THE USE OF OPERATIONAL WEATHER AND CLIMATE INFORMATION IN FARMER DECISION MAKING, EXEMPLIFIED FOR THE SOUTH-WESTERN FREE STATE, SOUTH AFRICA

BY

Ms. GUGULETHU N.C. ZUMA-NETSHIUKHWI

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In the Faculty of Natural and Agricultural Sciences

Department of Soil, Crop and Climate Sciences

Agrometeorology Division

University of the Free State

Promoter: Prof. C.J. Stigter

Co-Promoter: Prof. C.C. du Preez

Bloemfontein

Republic of South Africa

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Declaration

I hereby declare that this dissertation submitted by me for the degree of Doctor of Philosophy at the University of the Free State, Department of Soil, Crop and Climate Sciences, Agrometeorology Division has been prepared by me with my promoter's guidance. It has not been submitted to any other University or Faculty. I agree that the University of the Free State has the right to publication of this dissertation.

Signature: ________________ Date: : 29 January 2013

Mrs. G.N.C. Zuma-Netshiukhwi

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Republic of South Africa

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List of Symbols and Abbreviations

A	Above
ADRM	Agricultural Disaster and Risk Management
AGIS	Agricultural Geo-Referenced Information System
AN	Above-normal
API	Animal Production Institute
ARC	Agricultural Research Council
ARC-ISCW	Agricultural Research Council-Institute for Soil, Climate and Water
ASO	August-September-October
AWS	Automatic Weather Station
B	Below
BN	Below-normal
C5	Catchment 5
CAgM	Technical Commission for Agricultural Meteorology
CFs	Commercial Farmers
CFS	Climate Field Schools
CSIR	Council for Science and Industrial Research
DAFF	Department of Agriculture Forests and Fisheries
DFID	Department for International Development
DiMTEC	Disaster Management Training and Education Centre for Africa
DJF	December-January-February
DST	Decision Support Tool
ECSZ	Ehler's Crop Suitability Zones
EA	Extension Agents
ET	Evapotranspiration
EWC	Early Warning Committee
FAO	Food and Agriculture Organization
FMA	February-March-April
FS	Free State
FSA	Farming System Approach
FSaD	Farming Systems approach to Development
FSDoA	Free State Department of Agriculture
GCM	Global Circulation Model
GIS	Geographic Information System

INSAM	International Society for Agricultural Meteorology
IPCC	Intergovernmental Panel on Climate Change
IRI	International Research Institute
ISCW	Institute for Soil Climate and Water
JFM	January-February-March
LRAD	Land Redistribution for Agricultural Development
MAM	Marc-April-May
MLM	Mangaung Local Municipality
N	Normal
NAC	National Agrometeorological Committee
NDJ	November-December-January
NDVI	National Difference Vegetation Index
NGO	Non-Governmental Organization
NMHSs	National Meteorological and Hydrological Services
NN	Near-Normal
NOAA	National Oceanic and Atmospheric Administration
OND	October-November-December
PDMC	Provincial Disaster Management Committee
RPFs	Resource Poor Farmers
SA	South Africa
SABC TV	South African Broadcasting Company
SAWS	South African Weather Services
SMS	Short Massage System
SON	September-October-November
SPAC	Soil-Plant-Atmospheric Continuum
SPI	Standardized Precipitation Index
TV	Television
UCT	University of Cape Town
UFS	University of the Free State
UN	United Nation
USGCPP	United States Global Change Programme
WMO	World Meteorological Organization
WRC	Water Research Commission

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Abstract

THE USE OF OPERATIONAL WEATHER AND CLIMATE INFORMATION IN FARMER DECISION MAKING, EXEMPLIFIED FOR THE SOUTH-WESTERN FREE STATE, SOUTH AFRICA

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This study demonstrates that participating commercial and resource poor farmers used weather forecasts and climate predictions for agriculture and other science-based agrometeorological advisories during most of the study period. The study took place in the south-western Free State, synonymously used in this study as Modder/Riet catchment, which encompasses two districts Motheo and Lejweleputswa. It was found that most farmers in the south-western Free State originally were not familiar with such agrometeorological products but relied on their experience and traditional knowledge for farming decision-making. Most commercial farmers, having more resources, performed better compared to the resource poor farmers.

The thesis especially exemplifies case studies linking science-based products/advisories and problem solving in the agricultural production environment for various farmers, where applicable through extension intermediaries. This particularly contributed to increasing the useful operational applicability of weather science, climate science and various fields of agricultural sciences. This must be seen as a contribution to science itself.

The analytical results from questionnaires conducted in 2008 and 2012, with partly overlapping farmers, indicated that farmers in the south-western Free State differ in agricultural practices, interests, needs, experience and skills. Therefore, provision of tailor-made products for respectively crop production, animal husbandry, agroforestry and veld management is needed. Such agrometeorological information/advisories and, where people can assist to establish them, services can be disseminated by sending them to key communication outlets that are readily used by most people such as television, freely available local newspapers, local radio, bulletins, ward committees, extension forums and early warning committees. Cell phones can be used where the message may have limited size. The agrometeorological details should entail relevant and specific products that are directly useful to the farmers, and the latter should be able to interact with the sources. For all farmers in the Free State to embrace the use of agrometeorological knowledge and understanding would ideally require the interaction with well-trained extension agents.

The study groups presented a very diverse situation in terms of experiences, challenges and needs that are related to their farming. The consequences of increasing climate variability needed greater emphasis as to farmer's ability to develop on-farm coping strategies and interventions. A successful farmer should understand the local trends in climate change and how agricultural outcomes are influenced. For example, the concept of response farming prepares the farmer to be aware of past and future climatic conditions and of the extent of increasing climate variability and related dangers and interventions to reduce vulnerabilities. The study also identified potential production areas for vegetables, herbs/spices, grain food, oil seeds, fruits and other products such as cotton and other fibers. Application of crop models such as Ehler's model and Eco-Crop 2 revealed the thermal and water requirements of these crops which are either fully or partially met in various parts of the catchment. Agricultural production in some parts of the study area can be

optimal under supplementary irrigation and where soil requirements are suitable. Analyzed long-term rainfall data assisted the farmers to select suitable crops for the area for diversification and sequential planting and determining the suitable planting dates and planting densities. Crop models were used to generate and evaluate a series of management practice scenarios. These outputs from the analyzed climate data and crop models were used to develop advisories that were tailor-made for the farmers. The decision trees handled in the last Appendix were also used to develop alternatives of agricultural management practices for different seasonal climatic conditions.

The majority of farmers in the south-western Free State prior to this study regularly experienced devastating disasters that were weather and climate related, such as rainfall scarcity and rainfall irregularity, floods, untimely frost events, wind storms that also perpetuated destructive wildfires, outbreaks of diseases and pests, uncontrollable weeds which required intensive labour, severe drought conditions and overgrazed grazing lands. Weather forecasts and climate predictions for agriculture and other science-based agrometeorological advisories should be used to guide the farmers in terms of which response actions/decisions on agricultural activities to take under the above conditions and this way to reduce risks. Such agrometeorological products should serve a crucial role in strengthening sound decision-making and sustainable food security.

Farmers used weather-related indicators in their traditional forecasting (mostly of rains and droughts) such as animal behavior, appearance of certain bird species, sprouting of aloe and other indigenous trees, accumulation of clouds, cloud types, appearance of certain insects, star constellation, shape of the moon and wind speed and direction. Agricultural decisions were made according to such traditional knowledge and understanding of environmental conditions of their local area obtained through years of experience. Understanding of the farmer's perception on climate is a critical step to facilitate effective communication on agrometeorological information/advisories/services.

The tendency of scientists to develop knowledge for journals in the library that does not reach any end-users should be changed. It is therefore the responsibility of researchers and intermediaries to ensure that farmers have access to quality agrometeorological products for the betterment of agriculture in the Republic of South Africa at large. The study divulged a noticeable gap between the producers (universities/research institutes/weather services and other environmental services) and suppliers (broadcasters, extension officers, other intermediaries) of information/advisories/services while the users are in bitter need of agrometeorological products for improved on-farm decision-making.

Participation of farmers in a series of monthly innovative workshops created a conducive environment for information exchange and training. It is advisable to conduct on-farm visits prior to the workshop/meeting days for proper preparations. This was to ensure that the monthly workshops were well-planned, productive and informative events. The manner in which this study was structured enhanced a bottom-up approach since it allowed participative approaches in close contact with the study groups, improving farming development by closing the gaps existing between developers, suppliers and users of agrometeorological knowledge and understanding.

This study can recommend that participatory interaction with the farmers using focus groups, buzz questions, word of mouth, study groups and workshops allows two-way participation. This helps to understand the user's perception of the advisories, it allows a platform for constructive criticism that should lead to improvement of products and introduction of actual services, which are user friendly and translated into vernacular languages. The best outcome of this study was that farmers learnt new things and shared their information and experience. This farmer to farmer extension should be recommended for reaching the highest number of farmers in an area. The remaining challenge for agrometeorological advisories/services providers is to supply reliable and skilled forecasts/predictions and other science based information for agriculture through dissemination methods that suit the farmer such as already mentioned above.

Chapter 1

Introduction and Background to the Study

1.1 Introduction

Agriculture in Sub-Sahara Africa as a whole and in South Africa in particular remains one of the main pillars of the economy, as to crop production, animal husbandry and employment (e.g. Oram, 1989; Barrios et al., 2008). Climatic elements, and their variability and change are crucial factors in agriculture. According to an old general definition by the World Bank (1986), food sufficiency is described as enough food to supply the energy needed for all family members to have healthy, active and productive lives. Enhancement of food security is necessary to sustain the growing world population and is one of the key challenges of mankind (FAO, 2001). Food security is one of the major challenges that developing countries in Africa experience (e.g. Vermeulen et al., 2012). For decades and decades the South African government pursued an agricultural policy that gives emphasis to food self-sufficiency (Van Zyl, 1994). Even though this objective was realized to a reasonably good extent, many people in South Africa are still food insecure and live below the poverty line

Agricultural production is supposed to ensure food security to the agricultural communities and the population at large, especially with regard to staple foods such as maize, wheat, sunflower, groundnuts, vegetables, herbs, fruits and some other tree products. It can therefore once and for all be concluded that crop production and agroforestry play a vital economic and socio-economic role. In addition to traditional knowledge that remains useful, worldwide, high yielding agricultural production and agroforestry have shown to be fully dependent on research. It is also largely recognized that appropriate systems for research may be crucial for development (Van Zyl, 1997) and knowledge transfer (Winarto and Stigter, 2011). Agrometeorological information is one factor which is imperative to successful sustainable agricultural production (Agrometeorology has been defined in Appendix 1.1). However, appropriate operational agrometeorological decision support systems are still to be well-developed for young countries, also in South Africa, and their application must be more properly assessed. Such practices will be of assistance in combining agrometeorological research and education into agrometeorological information, products/advisories and services and in improving awareness and preparedness of farmers in different agro-ecological zones, and with different cropping patterns and crop selections (Stigter, 2010). Therefore, science based weather forecasts and climate predictions are among the many agrometeorological services that should be made available to farmers in a well-organized extension form (Hansen, 2000; Stigter, 2010; 2011; Attri et al., 2011).

South Africa is not richly endowed with natural agricultural resources as high potential arable land is limited (Van Zyl, 1997). In most districts across the country arable land is not utilized for crop production but for merely grazing or for a combination of grazing and cropping. Agrometeorological information/advisories/services are increasingly being demanded by farming communities to be able to cope more efficiently with climate inconsistency and the rising incidence of extreme meteorological events, such as droughts (Appendix 1.3), floods, hurricanes, frosts (Appendix 1.4), wind erosion and new and old pests and diseases (Stigter, 2002; 2010). Therefore, agrometeorology remains one of the most important issues in improving sustainable production. Stigter (2008) well defined agrometeorology as a form of problem solving in agricultural production.

The provision of agrometeorological information, advisories and services is not merely focused on production but also on storage and distribution systems of the final products (Appendix 1.1, 1.2, 1.3, 1.4, 1.5, 1.12, 1.13 1.14). Agricultural production is highly influenced by climate change that is now known to come with increasing climate variability and more (and more severe) extreme meteorological events such as extreme temperatures, floods and droughts (e.g. Stigter, 2010). Therefore climate change leads to economic and food security risks as it has a major influence on sustainable agricultural production. With provision of agriculture related weather forecasts, climate predictions and other relevant products/advisories and services, and by learning to understand potential and limitations of local (traditional) knowledge, researchers could assist farmers to develop ways to minimize agricultural production disasters under the conditions of a changing climate.

Case studies have shown that South Africa is a land of contrasts, given that commercial farmers (Van Zyl, 1994) and resource poor farmers operate under completely different conditions. What distinguishes the two groups of farmers is that a large number of resource poor farmers operate outside mentorship from information and services developers such as educational, research and environmental services institutions and technical extension services are insufficiently operational and updated and therefore do not meet farmers' needs. But interestingly, many commercial farmers are exposed and have access to institutional support structures and this includes access to finance, marketing strategies and technical extension services.

Therefore, integration of well researched local knowledge on farming systems and adaptation strategies with science based information, products/advisories and services are the key to successful sustainable agricultural production. Agrometeorological information exchange platforms need to be instated at grassroots level for potential users in farming communities, especially those communities where agricultural production is low and food insecurity is widespread. In this study the content of information is developed according to farmers' needs in a particular manner, because dissemination of available agrometeorological information, products/advisories and services remains undoubtedly imperative to improve adaptation to the consequences of climate change. Especially weather forecasts and climate predictions particularly generated for agriculture do hardly exist and the general ones are not well understood by most farmers since there is use of probabilistic language. Amongst other things, extension intermediaries should play a major role in science based information, products and services dissemination and learning of (that is knowledge transfer to) farmers. A two-way communication between role players, which are agrometeorologists and/or forecasters, and the end-users (in this case farmers), is necessary to maintain the continuity of interaction and open communication (Relationships Foundation, 2004).

We need a concept of response farming which focuses on improved decision making in cropping systems planned around rainfall forecasts/predictions for agriculture as agrometeorological or climate services. This will prepare farmers to make better informed decisions that are guided among others by the understanding of the operational applications of weather forecasts and climate predictions. Because inter- and intra-seasonal weather variations highly influence agricultural development and production under the conditions of a changing climate, farmers will obtain good yields by proper planning and preparedness. While having this in mind it is very important to clearly distinguish between agrometeorological information, advisories/products and services.

1.2 Description of agrometeorological products

1.2.1 Description of agrometeorology

Agrometeorology is the abbreviation of agricultural meteorology. According to Stigter (2002), agricultural meteorology uses the science of meteorology in the interest of enhancing agricultural production and food security. Agricultural meteorology cuts across scientific disciples and bridges physical and biological sciences. In shorter terms it can be described as an interdisciplinary holistic science (Mavi and Tupper, 2004). Agrometeorology is the science investigating the interaction between meteorological, climatological, hydrological factors and agriculture, including horticulture, animal husbandry and (agro) forestry. In this manner it has various applications in natural resource utilization and management and has advanced rapidly in developed countries and is progressing in developing countries. As an applied science it is has to be operational in problem solving.

Agrometeorology can further be considered as the science that uses weather (including weather forecasts) and climate (including climate predictions) information, advisories/products and services to improve/protect agricultural crops and/or to increase crop production. Interestingly, a multidisciplinary approach is crucial as agrometeorology overlaps with many other agricultural disciplines such as agronomy, soil science, animal science, climatology, plant pathology and many others (Stigter, 2012).

An enormous amount of water is required for agricultural purposes. When referring to water in agricultural production, rain plays a major role as it is one parameter that determines crop development status and demands appropriate cultural practices. The agricultural sector is the most water consuming sector (Shiklomanov, 2003), particularly in countries with low industrialization and recreational development, since supplementary irrigation is required during prolonged dry spells and drought episodes. Agro-ecosystems are an overwhelmingly complex process of air, water, soil, plants, animals, micro-organisms etc. in a bounded area that people have modified for the purposes of agricultural production. An agro-ecosystem can be of any specific size; it can be a single plot, or a household farm or it can be the agricultural landscape of a village, region or nation (Van Zyl, 1997). So basically, in agrometeorology we may also say that we deal with the environmental aspects of agro-ecosystems.

1.2.2 Agrometeorological information

Stigter (2012) differentiated between weather/climate *information, advisories* and *services*. In his view, *information* in meteorology/climatology is passive in the sense that there is no indication coming with that *information* on how to use it. "Raw" weather forecasts and climate predictions are examples. *Information with recommendations* on how to use it, or information otherwise made more *client-friendly* for solving specific problems, may be called *advisories*. But *dialogues* between senders and receivers are still not necessarily involved. In the USA, an *advisory* is only an official *announcement* or *warning*, while for example in India it is a *recommendation*, that is, however, not compulsory nor enforceable. Establishing such *advisories* with farmers in their fields should be called *services*. Then we have *dialogues* between farmers and extension. Then farmers are assisted to carry out the *advisories* (establish the *services*) in their fields, jointly with extension intermediaries and/or farmer facilitators, who were shown and trained how to do so (Stigter, 2012). In this thesis we use "advisories" and "products" as synonyms.

According to Weiss et al. (2000) information can be described as the basis to well informed agricultural decision making. Agrometeorological information begins with monitoring, collection, quality control and value adding of meteorological data for agricultural purposes. Meteorological data includes measured parameters such as rainfall, minimum and maximum temperature, wind speed and wind direction, radiation and humidity, which may be collected using routine observational stations or automatic weather stations. Long-term climatic data and its derivatives serve a great purpose to quantify information/advisories/products such as averages, patterns, frequency distributions, degree days, soil water requirements and drought indices. Agricultural or agronomic data is collected from experimental sites such as field trial plots as well as from farmers' fields. In order for agrometeorological information/advisories/services to be useful and meaningful to the end users, it/they must be accurate, timely, and cost effective. The benefit to be gained from implementing them must be greater than the cost to obtain and transfer them. Both meteorological and agricultural data are used in a synthesis which may guide farmers on their agricultural activities such as selection of crop type and/or variety, planting, water use management, weeding, application of fertilizers and pesticides and harvesting (Hashemi, et al., 2009; Hoogenboom, 2000).

Crop models may provide a more quantitative system for modelling crop growth and development, crop yield, irrigation scheduling, weed control, application of fertilizers and pesticides. In short, modelling requires process dynamics, a set of genetic coefficients and relevant environmental variables (Monteith, 1996). Models are good tools to conduct research and develop complicated information more effectively, among others to minimize risks that affect agricultural production. Crop models also may develop the ability to utilize long-term climate data to provide long-term yield or other agricultural impacts, which can serve to quantify risk (e.g. Rivero Vega, 2012). However, the accuracy of projected climate data is presently insufficient to use for experiments on field scale (Ramirez-Villegas and Challinor, 2012). Outputs from crop models can be utilized to develop products/advisories which entail recommendations to advance improved operational (that is strategic and tactical) decision making in agriculture. The dissemination of such advisories/products and related services is another very important component in development of agriculture. This requires well trained intermediaries to improve farmers' knowledge and decision making in management practices and to learn from farmers for sustainable production (Stigter, 2010, Weiss, et al., 2000, Sivakumar, 2006).

1.2.3 Agrometeorological advisories/products

Agrometeorological advisories refer to value added products that provide sufficient client-friendly guidance on favorable and unfavorable weather and climate conditions as well as suitable agricultural practices (including protection measures) in a particular area or region. For example weather forecasts and climate predictions for agriculture could be given as advisories/products that can guide farmers to select best possible agricultural practices for productivity improvement and/or protection. Given earlier made distinctions, this would only become an agrometeorological/climate service when farmers could interact with those that made or carried these forecasts and prediction products.

Advisories are crucial for agricultural planning and management. The advisories are developed in different formats such as in client friendly focused bulletins, pamphlets and publications. This special type of advice is mostly created by agrometeorologists for the farmers; hence the need for training of intermediaries (extension agents) is very crucial to get such advisories into services (Stigter, 2010). Advisories may for example recommend certain practices to be implemented, selection of a particular crop or variety to be planted, or establishment of measures to effectively minimize weather related crop damage. Such damages may include contamination of soil, air pollution damage of plants and soil erosion from wind and water, They may also be due to agricultural drought, (a given extent of) pests and diseases, (certain frequencies and severities of) frosts, the occurrences of forest and bush fires, losses during transport and storage and all farm operations (Mavi and Tupper, 2004; Rijks and Baradas, 2000). In short, agrometeorological advisories provide practical solutions in operational (both strategic and tactical) planning, for utilizing weather and (micro) climate information for minimizing of climate related risks. Again, only when the providers of such advisories interact with farmers on establishment of these advisories in farmers' fields, we can talk about services rendered.

1.2.4 Agrometeorological services

Operational agrometeorological services in developed countries are reasonably advanced comparing to even the best-off developing countries (Stigter, 2008) such as South Africa. It must in fact be noted that in most developing countries agrometeorological services are not systematically provided and most often are simply non-existent (Stigter, 1999; Weiss, et al., 2000, Sivakumar, 2006, Stigter, 2008, Stigter, 2010). Agrometeorological services can contribute to good quality on-farm produce and national economy (Richardson, 2000) and can obtain remuneration for the investment made in agrometeorology, through effective utilization of tailor made advisories (Rijks and Baradas, 2000). Improvement of agrometeorological services may close the gaps between information inventors and users. Therefore, incorporation of agrometeorological services in the livelihood of farmers remains a crucial matter that needs to be enhanced. Stigter (2007) considered belonging to agrometeorological services all agrometeorological and agroclimatological information that can be directly applied to try to improve and/or protect the livelihood of farmers in agricultural production, so yield quantity and quality and income, while safeguarding the agricultural resource base from degradation. From this definition it is clear that we are talking about establishment of services in farmers' fields. In the same publication Stigter (2007) distinguished the following examples of such services, including the set-up of pilot projects for on-farm validations:

- products of agroclimatological characterization, obtained with whatever methodologies;

- advices such as in design rules on above and below ground microclimate management or manipulation, with respect to any appreciable microclimatic improvement: shading, wind protection, mulching, other surface modification, drying, storage, frost protection, etc.;

- advisories based on the outcome of response farming exercises, from sowing window to harvesting time, using climatic variability data & statistics of a recent past or simple on-line agrometeorological information;

- establishing measures reducing the impacts and mitigating the consequences of weather and climate related natural disasters for agricultural production;

- monitoring and early warning exercises directly connected to such already established measures in agricultural production, to reduce the impacts and to mitigate the consequences of weather and climate related natural disasters for agricultural production;

- climate predictions and forecasts and meteorological forecasts for agriculture and related activities, on a variety of time scales, from years to seasons and weeks, and from a variety of sources;

- development and validation of adaptation strategies to increasing climate variability and climate change and other changing conditions in the physical, social and economic environments of the livelihood of farmers;

- specific weather forecasts for agriculture, including warnings for suitable conditions for pests and diseases and/or advises on countervailing measures;

- advices on measures reducing the contributions of agricultural production to global warming and keeping an optimum level of non-degraded land dedicated to agricultural production;

- proposing means of direct agrometeorological assistance to management of natural resources for development of sustainable farming systems in technological advances with strong agrometeorological components;

These fields of agrometeorological services were maintained and exemplified in later publications (Stigter, 2010; 2011). They include, for example, the use of shade against excessive heat, frost preventative measures, anti-erosion measures, establishment of wind breaks and efficient use of pesticides and herbicides. Many more examples as case studies may be found in the above mentioned publications. But for a successful adoption of agrometeorological services by farmers, understanding of local adaptive strategies and innovations remains also very important. In these ways, provision of agrometeorological advisory services to farmers in developing countries can improve agricultural production remarkably.

1.3 Dissemination of agrometeorological information/advisories/service

Communication of agrometeorological information/advisories/services is most crucial for agricultural productivity and alleviation of food insecurity. The World Meteorological Organization (WMO) specializes in meteorology and operational hydrology to establish networks for information exchange, research, training and technology transfer. WMO's responsibilities are to assist all regions worldwide to develop sustainable and economical viable agricultural systems (WMO, 1997). Within WMO these tasks are carried out by the Technical Commission for Agricultural Meteorology (e.g. Stigter, 1999). When scientific skills have been developed in operational aspects of agrometeorology and after they have been worked into advisories/products and services, they need to be integrated, deployed and communicated (Monteith, 1993, Rijks and Baradas, 2000, Stigter, 2010). An effective communication needs to follow a few key guidelines. It should include the participation of the end-user from the development phase, to learn about interpreting and operationalising the information. Identification of users, their specific requirements, and their perception of the products/services and preferred methods of their dissemination are the key points to successful delivery. One of the important reasons of presently failing strategies is the lack of adequate interaction with the user community in assessing the appropriate dissemination and communication procedures that can enhance the value of agrometeorological information and services (Mukhala, 2000; Ziervogel, 2004; Stigter, 2011). A two way communication from sender to receiver and receiver to sender is very important to upgrade existing advisories and develop more user friendly advisories (Mukhala, 2000; Stigter, 2010).

In Europe, a number of private sectors have recognized the importance and are communicating agrometeorological advisories (Pérarnaud, 2004) but their absorption and use, leave much to be desired (Wieringa, 1996). Such suppliers of agrometeorological information/products/services in Europe are well organized in each country. There are also National Meteorology and Hydrology Services (NMHSs) which provide some agrometeorological advisories to farmers but again to relatively little avail (Wieringa, 1996). It is also noted by Pérarnaud (2004) that feedback from farmers is not received and that the economic value of the application of agrometeorological information is not assessed.

Across the African continent agrometeorological services have lagged behind and as a result the agricultural production is decreasing on a yearly basis (Sivakumar, 2006). Many countries in Africa are experiencing a frequent shortage in grain crops and this is a result of increasing climate variability and the related climate change. The Northern part of Africa experiences frequent droughts while the Southern part of Africa is prone to frequent floods. Both these occurrences affect the farmers tremendously. Therefore, strengthening of agrometeorological services in partnership with governmental departments, private partners and research institutions may improve such services and the standards of agricultural production. NMHSs also exist in Africa, as well as independent agrometeorology units. In some countries the latter are based within the agricultural ministries or departments.

Agrometeorological discipline in South Africa is categorized as a scarce skill (Lumsden and Schulze, 2013). Therefore, agrometeorological services are lagging behind due to the scarcity of individuals well-trained to lead in the field of agrometeorology. However, there are initiatives across the country to empower the farmers and other users with agrometeorological information, advisory services and products. For examples agrometeorological services have been initiated by the Department of Agriculture, Forestry and Fisheries (DAFF) under the unit of Agricultural Disaster, Risk Management and Farming Information in partnership with the Universities, Research Council and private organizations.

1.4 Problem Statement

The south-western Free State experiences hot summers with moderate to low rainfall and cold, dry winters frequented by severe frost (SAWS, 2009). Climate conditions differ between regions and have a significant variability within seasons as well as between seasons. Interaction and inter-control between climatic conditions and soil, topography, hydrology and vegetation exist in every location. Climate change and the related increasing variability as well as their impacts, complicate effective management of natural resources, sustainable agricultural production and food security (e.g. Hulme, 1996; Stigter, 2008). As we also already have seen in the above, it is crucial to improve the application of weather and climate information, advisories/products and services for on-farm decision-making that will sustain these fields of agricultural production by introducing applied science-based management interventions (see also Hartung, 2003; Mafongoya et al., 2008, Stigter, 2010; Attri et al., 2011). For example, in crop production this means understanding of crop suitability, breeding aims, adjustment to inter-seasonal rainfall variabilities and intra-seasonal rainfall distributions. While in animal production this means creating an acceptable micro-environment with shelter temperature and ventilation as primary control variables. Productivity levels in semi-arid areas remain below the levels that are potentially feasible, although appreciable progress has been made at various places (Ahliburg et al., 1996; Vermeulen et al., 2012).

As an example of new trends, seasonal climate prediction has stimulated significant interest from potential users such as large-scale farmers, and the insurance and banking industries (e.g. Blench, 1999; Hansen et al., 2011). Seasonal climate predictions are a potential tool that can assist individuals and organizations in coping with and adapting to increasingly variable and changing climate conditions (Klopper et al., 2006; Hansen et al., 2011). Making seasonal predictions or scenarios based on such predictions available (to among others commercial as well as small-scale producers) could assist farmers that seriously observe rainfall and its consequences for their agro-ecosystems to increase food security as well as to cope better with disaster strategies (e.g. Winarto and Stigter, 2011). According to Blench (1999), in southern Africa there is a considerable gap between agrometeorological results needed by the farmers and that given by the Meteorological Services. This is confirmed by more recent reviews (e.g. Hansen et al., 2011, Vermeulen et al., 2012). It was also very recently still stated that while considerable advances have been made in the collection, archiving and analysis of weather and climate data, their transformation into products like climate predictions that can readily be used by the farm sector has lagged behind (Hansen et al., 2011). This especially holds for resource-poor farmers where such information needs are even higher.

Over the last decades it has been stressed, among others by the Technical Commission for Agricultural Meteorology (CAgM) of the United Nations (UN) World Meteorology Organization (WMO), that provision of agrometeorological information, advisories and services used for decision-making, are part of a continuum that begins with scientific facts and understanding and ends with assessment of the use of that information and its on-farm applicability (Stigter, 2007; Vidal, 2009, WMO, 2009; 2010). This also applies to climate predictions.

Potential applications of seasonal predictions are broad, with the greatest value ascribed to the planning stages of operations. Farmers must make management decisions relating to the amount and timing of applications of inputs, choice of crop and crop cultivar, when to plant, fertilization rate, planting density, etc. (Vogel, 2000; Klopper et al., 2006). Effective operational products such as science based climate predictions with sufficient actual skills can also help farmers to feel more in control of their lives, and can give them greater confidence with the choices that they make (Patt and Gwata, 2002; Hansen et al., 2011). Traditional weather forecasting and climate prediction have to be taken into consideration for a thorough and fair comparison of traditional and science based knowledge and understanding (Zuma-Netshiukhwi and Beinzonhuit, 2008). What has been exemplified here, in this problem statement with climate predictions for agriculture, applies to all relevant weather and climate information/advisories/services in agrometeorology.

1.5 Selection of the Study Area

A few of case studies showing the on-farm situation found at the start of the study are given on Appendix 1. Regular meetings and workshops across Modder/Riet catchment (Fig 1.1) were conducted with commercial farmers, resource-poor farmers and extension officers. For this study the Farming Systems approach to Development (FSaD) was used (Friedrich et al., 1994; Tripp, 1999; Matata et al., 2001, Bamal et al., 2006) to interact with the participants in selected areas. Stakeholder workshops were conducted to identify their roles in the farming sector with an analysis on their perceptions and need assessments for verification. The FSaD approach has been chosen for this study because it involves working directly with the farmers, in a bottom-up orientation. It also facilitates linkages amongst groups of farmers, individual farmers and between extension intermediaries/officers and farmers (Friedrich et al, 1994; Tripp, 1999; Matata et al., 2001; Bamal et al., 2006). The FSaD where appropriate was supplemented by an action learning cycle which was adopted from the Action Research Approach (Dick, 2002; McNiff, 2002; Tenge, 2005; Kramer, 2007; Stringer, 2007; Serrat, 2008; Kelman et al., 2009). See for further details Chapter 4. It will also be strengthened with other participatory tools and techniques that are compatible with the whole farming system, where one facet of the system requires improvements within that particular focus.

Agrometeorological advisories/services will be developed according to the needs of the farmers based on their agricultural activities and potential agricultural enterprises. The agroclimatological zones, average annual rainfall (Fig.1.2), thermal time and soil types largely determine the potential for agricultural enterprises in a specified area. For example, the catchment selected has noticeable differences in average annual rainfall, with the western part of the catchment ranging from 301-400 mm/annum, the middle part ranging from 401-500 mm/annum and the eastern part ranging from 510-600 mm/annum (Fig. 1.2)

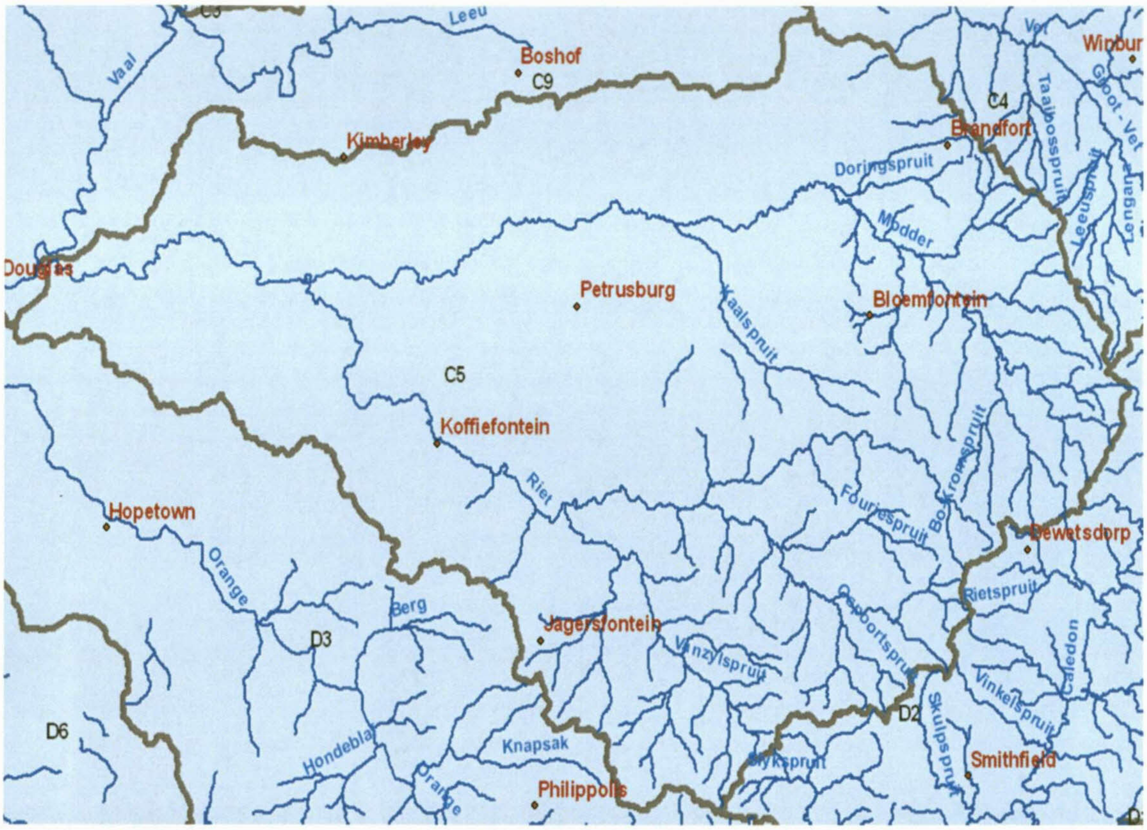

Fig.1.1 Representation of Modder/Riet catchment which was the study area (*www.dwarf.gov.za*).

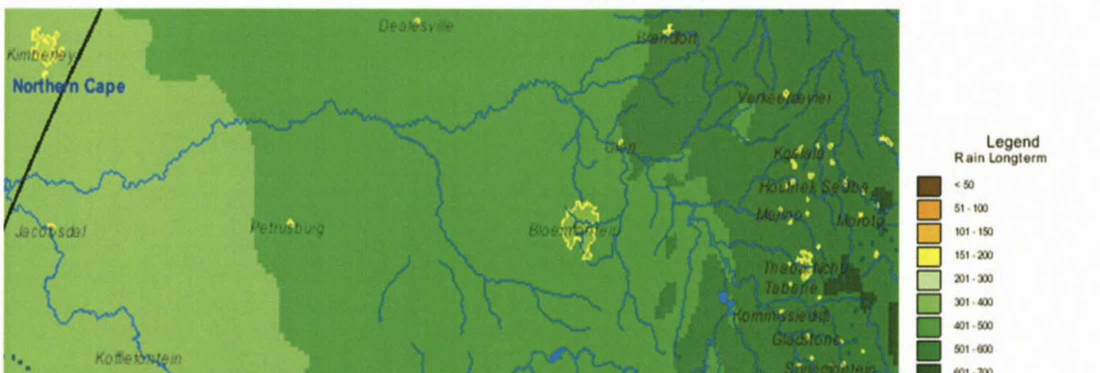

Fig.1.2 The long-term annual rainfall distribution across Modder/Riet catchments (*http://www.agis.gov.za*) (see also Chapter 3)

1.6 Research Questions in Agrometeorology

a) What is locally available, used as traditional weather/climate information and forecasting/prediction methods and what of this will remain useful under conditions of a changing climate?
b) Are the quality and skills of the available science based information and products such as forecasts/predictions suitable for the ever-changing needs of farmers?
c) How can the resource poor farmers best apply science based weather/climate information and advisories/products to improve crop, tree and animal production? How do we determine their success?
d) Will accessibility to science-based forecasts/predictions with enough skill and some other useful information and products encourage farmers to adopt alternative and more sustainable agricultural planning and activities?
e) When advisories/products are made available, will farmers be able to understand and apply the information so provided? How can farmers improve their understanding and use of such information and advisories?

1.7 Overall Goal of the Study

The overall goal of the study was to explore examples of agricultural on-farm decision-making changed due to the availability of science-based climate/weather information/advisories in comparison with the traditionally used information. Ultimately, the farmers will be asked to make the comparison where applicable. This means that the thesis especially will exemplify with case studies linking science-based products/advisories and problem solving in the agricultural production environment for various farmers, where applicable through extension intermediaries. *This particularly contributes to increasing the useful operational applicability of weather science, climate science and various fields of agricultural sciences. This must be seen as a contribution to science itself.*

1.8 Objectives of the Study

The objectives of the study were:

a) To compare agrometeorological information standards and methods used to disseminate information/advisories, in more developed countries and in still developing countries, for commercial farmers and resource poor farmers.

b) Identify farmers, describe base line support systems, and ascertain qualitative research methods suitable to interact with the farmers within Modder/Riet catchment.

c) To assess and address some relevant climate/weather sensitive decisions of farmers and their adaptation and mitigation options for such decisions in agricultural activities in crop production, animal production and agroforestry.

d) To effectively cope with and adapt to some disastrous weather/climate events through science based interventions that minimize or decrease the impact of such events and promote sustainable agricultural production through improving emergency response capacity.

e) To critically reflect on the skills and consistency of a series of tailor-made advisories as the output of the decision support tools with the background of an ever-changing climate.

1.9 The Value of the study

There are insufficient water resources to meet the growing water requirements from a range of sectors in the Modder/Riet catchment, which is located in the southwestern Free State Province of South Africa. The water supply comes from the adjacent Caledon River by means of the Caledon-Modder river government scheme (Fig.1.1). During prolonged dry spells and intensive drought episodes, water becomes unaffordable for farmers to provide supplementary irrigation, resulting in reduced agricultural production. Irrigated agriculture is currently the largest consumer of Free State's insufficient water resources (www.dwarf.gov.za). Moreover, resource-poor farmers are disadvantaged because they have hardly any access to irrigation water because they can't afford it.

Resource poor farmers and commercial farmers must more and more rely on natural rainfall, which is not sufficient for their demand. Therefore, provision of weather/climate forecasts/predictions and other value added seasonal product information could give support to farmers for improved decision-making under such conditions. Assisting the farming sector to utilize the rainwater more effectively and to understand the rainfall variability dynamics and the adaptation strategies to undertake would therefore be of significant value to the farming communities (Tadross et al., 2005; examples in Stigter, 2010 and in Attri et al., 2011). To show that would be the value of this study.

In the Modder/Riet catchment, south-western Free State, the unsatisfactory level of food security and of the sustainability of agricultural production is alarming. Most people rely on rainfed agriculture for their livelihood, frequently farming on marginal and fragile soils (MEDS, 2003). Lack of adequate water from water sources, erratic rainfall, severe cold conditions during winter, frequent drought events, outbreak of diseases, fire occurrences and poor farm management are major constraints to enhancing agricultural production and generate income. For example, the impact of drought interrupts cropping plans, reduces breeding stock, destroys critical ecosystem services and promotes soil erosion, which all decrease farming productivity (Wilhite, 2000; Farley et al., 2012). Over the past decade, agricultural scientists have introduced some water and soil conservation techniques to improve crop production (MEDS, 2003). Any sustainable production techniques, used simultaneously with agrometeorological information/advisories/services such as seasonal rainfall predictions, could result in more stable and sustainable production (Bolens, 1997; Hansen et al., 2011) but this leaves actually much to be desired (Archer et al., 2007; Hansen et al., 2011).

Various Services in South Africa and elsewhere in Africa jointly developed an information system on probabilities of rainfall and temperature concurrencies being above, around or below certain observed thresholds (e.g. Ogallo et al., 2008). For resource poor farmers such forecasts/predictions need interpretation, value addition and well organized dissemination to become advisories. Therefore, this study will use collated forecasts/predictions from different institutions such as the South African Weather Services (SAWS), the University of the Free State (UFS), the Council for Science and Industrial Research (CSIR) and the University of Cape Town (UCT). Moreover, this study will ensure that the targeted end-users community for these agrometeorological advisories will have access to these advisories by identifying the proper channels and suitable methods of their dissemination for various groups of farmers.

African farmers need to be encouraged on the application of agrometeorological information and products, such as in response farming (e.g. Stigter and Winarto, 2012), to improve yield production by monitoring on-farm weather, particularly rainfall, and applying this information in daily management decisions (Stewart, 1988; Van der Zaag, 2010; Stigter et al., 2011). Previous studies have shown that monthly, seasonal and inter-annual variability of rainfall and temperature inconsistencies across Southern Africa are to a certain extent known and therefore simple probabilities are to a certain extent predictable (Reason & Rouault, 2005). However a great challenge remains, because the importance, acceptance and reliability of these predictions are unclear. Moreover, it is a necessity to train the farmers to enable them to know how to make use of these products (Stigter, 2011). For example, in the crop production sector the onset, distribution and cessation of rainfall are crucial but very difficult to predict long in advance. Only simple seasonal scenarios may be derived from the climate predictions.

Therefore, through this study the production of value added and tailor-made advisories with interpretative guiding principles and through proper channels of information distribution, will aim at progressing and improving the adoption and value of weather/climate information/advisories. This must be done to the point where it will become a routine for agricultural operational strategic and tactical planning. Through this project, farmers should be able to better plan their practices, having suitable agrometeorological information/advisories for response farming and contingency planning. Understanding of inter-seasonal, intra-seasonal and intra-annual climate variation from climate signals would be the most imperative, since these are major factors affecting yields and production. But this is actually still beyond what applied climatology has to offer in simple probability predictions. For weather forecasting 3 to 5 days and for climate prediction one to three months is the best we have to offer and this should therefore be renewed every one to three days and every month respectively. That is what happens in practice also to any attempts of forecasting and prediction for any longer periods such as a week, 14 days or beyond three months. For response farming applications, we also make use of studying similarities between actual developments and longer-term behavior of weather and climate phenomena in various seasons. This is better than statistics but less than understanding cause and effect relationships and under conditions of a changing climate is only operational for data over the last ten years or so.

Weather/climate forecasts/predictions produced are not point specific, but only cater for larger areas within the catchment or for the catchment as a whole. Therefore, forecasts/predictions to be used for this project will be down-scaled to Modder/Riet catchment at a lower resolution and they will then be more applicable to the needs of the farmers. However, it needs to be understood that downscaling always means loss of accuracy of the probabilities predicted.

Valuable information produced for farming communities has not been well communicated. The reason for this is mostly a lack of well-trained intermediaries and well-structured communication channels (e.g. Stigter, 2011). The linkage between the sender and the receiver is therefore defective. This work intends to show how to narrow this huge gap by developing channels whereby the end-users (commercial and recourse poor farmers) can get improved access to such information and will be able to apply it in their on-farm decision-making. Furthermore, extension officers from the Department of Agriculture, Forestry and Fisheries will be trained "in-service" to better understand and be able to transfer agrometeorological information/advisories, when they work hand-in-hand with the farmers. This will contribute to the value of the study.

1.10 Methods

This research will consist of three major parts, which are:

i. interaction with the community
ii. understanding of the farming systems concerned
iii. development of advisories using existing weather/climate information products.

1.10.1 Farming Systems Approach

The Farming Systems approach to Development (FSaD) is eventually complemented by the use of participatory tools (e.g. questionnaires, discussion in groups and with key informants, buzz questions) and techniques (e.g. a Participatory Rural Appraisal Approach). An action learning cycle will be used in the FSaD where necessary, leading to the improved dissemination and application of weather/climate information and products/advisories in agrometeorological decision making for improved livelihoods. The FSaD will be applied with the following objectives in mind for the south-western Free State:

a) to analyze the farming systems for their indigenous knowledge, particularly on rainfall forecasting,
b) to understand current agrometeorological advisories and services (if any) and sources of weather/climate information,
c) to identify and select appropriate channels for information communication/dissemination,
d) to develop some tailor-made advisories together with farmers for improved on-farm decisions making for such matters as crop type, cultivar and planting date selection,
e) to monitor and evaluate the use and adoption of these advisories,
f) to discuss these matters with farmers in monthly meetings,
g) to derive rules for procedures, without scientists being involved each and every time, for creating
    1. extension potential

2. extension training
3. extension practice.

Action learning cycle (plan-act-observe-reflect) (Dick, 2002; McNiff, 2002; Tenge, 2005; Kramer 2007; Stringer, 2007; Serrat, 2008; Kelman, et al., 2009) will be neatly used to supplement the FSaD to interact with existing study groups, individual farmers and extension intermediaries to establish and describe the current farming systems. Subsequently, introduce agrometeorological information/products and then study the problems with and the impact of some relevant applications.

All methodological developments will be reported in Appendices, away from the main story of this thesis that is centered on how the target groups make use of the agrometeorological information, advisories and services available and accessible to them.

All the above objectives will be implemented with the guidance of an iterative action research learning cycle within the following stages of the farming systems approach (Fig. 1.3).

i. **Diagnosis/Description** of farmers' needs in relation to the agrometeorological information and advisories/services using diagnostic surveys, including relevant qualitative and participatory methods. Identify typologies within the farming community and among stakeholders relevant to the system.
ii. **Design Planning** of the scenarios per agricultural enterprise through the use of participatory tools and techniques such as workshops, focus groups, key informants, formal and informal interviews, action planning, look and learn, role-play, learn by doing, observations and transect walks.
iii. **Testing and Implementation** through farmer-managed experiments according to planned interventions and activities. Provision of agrometeorological advisories/services with detailed agrometeorological information/advisories, such as on sowing dates, crop cultivars, soil water capacity, irrigation scheduling, rainfall probabilities, etc.

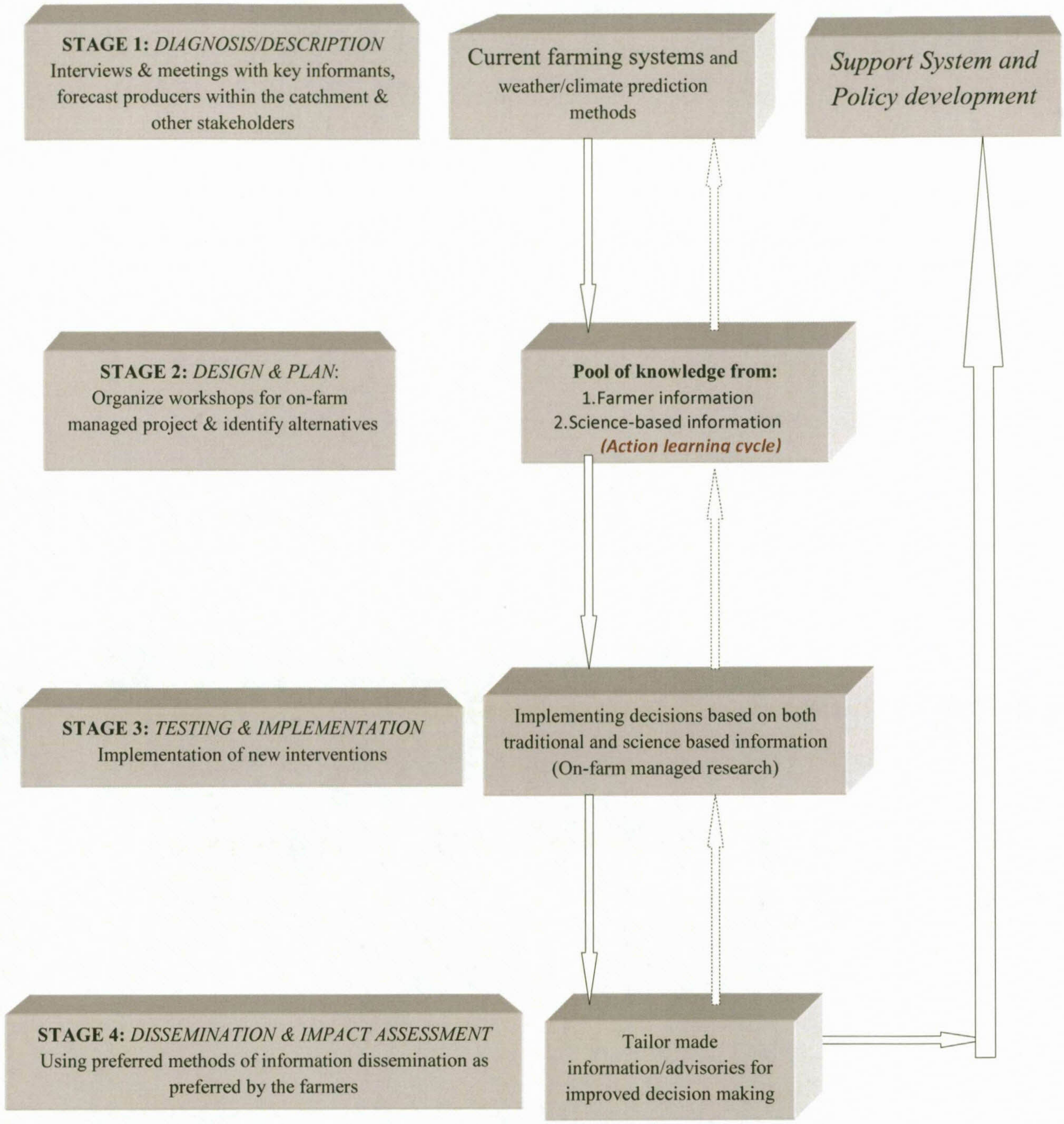

Fig. 1.3 An illustration of the research process to be used in Modder-Riet catchment to promote the use of climate/weather information products/advisories in crop and animal production and agroforestry.

iv. **Dissemination and impact assessment** using dissemination methods as preferred by the farmers, for example bulk SMS, monthly meetings, on-farm visits and internet. Strategies that would be identified and screened during the planning and testing of implementation stages are sent to the users of information. This stage facilitates the dissemination and impact assessment by the monitoring and evaluation of the adoption of science-based weather/climate information and advisories/services and its impacts. At this stage, future priorities could be developed based on the weather/climate information predicted.

The selection of this illustration (Fig. 1.3) of the research process to be used in Modder/Riet catchment, integrates the action learning cycle (plan-act-observe-reflect) in stage 2 (Design & Planning) of the farming systems approach. These approaches will be used concurrently to promote the use of climate/weather information/advisories in crop and animal production and agroforestry in interaction and exchange of information with the farmers.

1.11 Development of advisories

1.11.1 Long-term data analysis

Long-term climate data will be obtained from all automatic, mechanical and on-farm weather stations available across Modder/Riet catchments and identify patterns of onset, distribution and cessation of rainfall. Analyze mean rainfall (monthly, 10 & 5 days), seasonal distributions, onset/cessation, probabilities of amounts (1, 5, 10 and 20 mm) and dry spells. These analyses will be conducted using INSTAT Plus and excel spreadsheet. Forecasts/predictions will be interpreted and analyzed value-added advisories will be developed and disseminated to identified end-users (farmers). The weather forecasts and climate predictions will be received from the South African Weather Services, downscaled forecasts from the Council for Science and Industrial Research (CSIR) and the NOAA ensemble climate predictions for South Africa.

1.11.2 Description of crop models

The crop models selected for this research are: Ehler's Crop Suitability Zones and ECO-CROP 2. ECO-CROP 2 is a Food and Agricultural Organization (FAO) developed Crop Environmental Requirements Database and Crop Environmental Response Database. It is a tool for recording, organizing, comparing, and using studies on crop response to environmental and management factors. It allows users to identify suitable crops for a particular environment, identify a crop for a defined use, and look up the environmental requirements and uses of a given crop. This model should assist to identify other crops recommended for farmers to diversify their cropping and farming systems (http://ececrop.fao.org). The farmers should be able to identify alternative crops that could suit their environmental conditions.

Ehlers Crop Suitability Zones, specifically developed for South African crop conditions, will be used to specify the suitability of crops for the study area and their adaptability to that environment (Ehlers, 1988). Crops are divided into zones according to the plant temperature requirements. The zones are identified by four digits, the first two digits represent the average temperature for summer months and the last two digits represent the winter months day and night average temperatures. The conditions are given as optimal (crops well suited for a specified environment), sub-optimal (crops that can grow in a specified environment with consideration of selecting or controlling their climate conditions) and marginal (crops that are not adaptable to a specified environment).

Downscaled data from multi-model (ensemble) seasonal forecasts provided by the forecasting group in South Africa will be used as a guideline to develop value-added products. The outputs from crop models will be developed into advisories and tested by intermediaries that attend to farmer's needs and are familiar with the existing environmental conditions and agricultural activities practiced.

1.12 Benefits of the Study

This project will supply agrometeorological advisories to benefit the end-users in the agricultural production sector. Selected farmers in the Modder/Riet catchment will have firsthand experience of the availability of agrometeorological information/advisories, their application for improved decision-making, and chances to raise their perceptions on the applicability, the importance and the reliability/skills of such information/advisories. We will attend to weather/climate information/advisories, their interpretation in the application of such information/advisories to agriculture, as well as the value of and the timely output from decision support tools. There will be derived products on the best planting date, the onset and cessation of rainfall, irrigation scheduling, spraying programmes, fertilizer application and the severity and timing of dry spells and longer droughts.

Chapter 2

Learning and Understanding the Use of Weather Forecasting and Climate Prediction in Modder/Riet Catchment

2.1 Introduction

It was a learning experience for me to conduct agrometeorology workshops in selected areas within the south-western Free State. It was another learning curve for the farmers to be exposed to scientific information for their daily practices. The study groups were introduced in early 2008 in the south-western Free State, the towns selected were within the Modder/Riet catchment, which was used as the boundary for this study. During this interaction with the farmers, it was recognized that most farmers were not exposed to agrometeorological information except for their local knowledge on farming. The farmers learnt various kinds of subjects related to weather forecasting and climate predictions. On the other hand, researchers learned farmer's indigenous knowledge related to weather and climate and its applications for fields and crops.

The concept of farmer field schools (FFS) was later on introduced to famers, which occurred at the beginning of the planting season as well as at harvesting and the last one occurred after the installation of two automatic weather stations in Sannapos. Learning in study groups was a great experience to most farmers, as farmers used this opportunity to exchange their experiences. Agrometeorological information and its application in operational strategic and tactical decision making were introduced during meetings. Such meetings with the farmers occurred on a monthly basis since 2008 and ended in June 2012. Farmers were delighted to learn new ideas that they had never heard of before: on weather forecasting, climate prediction and usage of probabilities, other (science based) weather/climate information and its application in crop and animal production and agroforestry. Progressively, new ideas were taught to farmers and their general ways of crop and animal production were enriched with a set of science based knowledge.

Interaction in study groups and meetings with the farmers who had their own knowledge and experience of weather/climate and interpretation of local weather/climate knowledge were events where a joint of creation of knowledge was perpetuated (Berliant and Fujita, 2006). Researchers and farmers were interacting from completely different perspectives to create and transfer knowledge for change. In this case both parties and individuals play a crucial role in establishing their own learning and findings through study groups and other qualitative participatory methodologies (Winarto and Stigter, 2011). Farmers were courageous in learning applications of agrometeorological information/products and they were actively sharing their knowledge, experiences and enthusiasm to incorporate agrometeorological information/products into their daily agricultural activities and decision making.

Interacting with the farmers created a place to understand their interpretation of weather/ climate information, challenges which are specific farm based and other challenges that affect farmers. As to the latter challenges, not only farmers but whole agricultural communities experienced increasing climate variability in their daily activities. Agricultural production in the south-western Free State is both under irrigation and as dry rainfed agro-ecosystem. The latter production is highly dependent on the availability of supplementary water to sustain crop growth and development (e.g. Sivakumar and Hansen, 2007) because of rainfall variability and amounts received (Ogindo and Walker, 2005). The study area is characterized as a semi-arid area which certainly explains its unpredictable and inconsistent rainfall at any time through the year. Long before the initiation of modern scientific methods for weather forecasting and climate prediction the farming continued successfully (Camberlin, 1997) when impacts were not too severe, as farmers utilized traditional ways and indicators of rainfall forecasting (examples are dealt with later on in this Chapter, see Table 2.1).

In Southern Africa, climate inconsistency is the core determining cause in the productivity and sustainability of farming systems (Tadross et al., 2005). Amongst others, soil degradation, decreasing water resources and changes in climate are also major impediments to sustainability of agricultural development. Farmers have relied on nature to determine the season of the year, and traditionally, the growing season is the period of the year which is determined predominantly by climate and crop requirements. It depends on the location, temperature, photoperiod and rainfall as the most critical environmental factors. The growing season is determined as days between last spring and first autumn frost in many higher lying areas (Kotzé, 1980) (see attached Appendix 1.4. for Glen Agricultural College, Bloemfontein and Lady Brant frost charts). Farmers are familiar with the relations between weather, crop suitability, crop selection and planting schedule in a particular season. When and what to plant is determined by integrated weather indicators and interpreting indicators within the environment. These traditional weather-related indicators and animal behavior are used as guidance for farmer choices on their farming activities (see Table 2.1 later on). We cannot be ignorant to indicators used by the farmers and must learn from it, since farmers have survived for decades and decades using local knowledge. However, farmers were more or less forced to learn the application of scientific information since some of the traditional indicators have disappeared from the ecosystem. For example, there are indigenous trees which were cut down for fuel, and bird species that migrated to other places (Zuma-Netshiukhwi and Beinzonhuit, 2008). The major challenge for the researchers was how to combine indigenous knowledge and science-based information/products and to actually train the farmers in interpreting and using the latter.

Farmers' vulnerability to climate abnormality often is caused by lack of resources and support systems, as some have no means to adapt rapidly (Kahn, 2003). Adaptation to increasing climate variability is essential to minimize consequences of new climate risks, and improved preparedness is essential for sustainable crop and animal production. Therefore, introducing agrometeorological information/products to farmers creates a platform for the development of a new range of different adaptation strategies for different agricultural enterprises, tailor-made on-farm. With the provision of seasonal forecasts of sufficient skill, critical decisions can be improved. According to Ziervogel et al., (2006), weather forecasting, climate prediction and other agrometeorological information/products are required for the reduction of risk in agricultural production.

Impacts of weather and climate on the implementation of agricultural activities from land preparation, planting, weeding, spraying, harvesting, storage to transport and marketing are recognized worldwide. Most farmers have no access to weather/climatic related information/products other than general weather forecasts. If there is some access, other factors diminish the use such as lack of understanding and interpretation for application, costs, reliability, interpretation of probabilities etc. Furthermore, the fact that information/products provided to the farmers are at high resolution and not point specific brings uncertainty (Seeley, 1994). Agrometeorological scientists have the mandate to ensure that weather/climate information/products and services are made available to the farming community for effective and profitable farming (Seeley, 1994). Information resulting from analyzed historical climate data and research studies on crop production in different environmental zones are not distributed among most farmers (Maunder, 1989; Gommes et al., 2010). However, technologies and approaches have more recently been proposed to support information dissemination at preferable lead-times, and in suitable specific formats as suggested by intermediaries and users (Gommes et al., 2010). But dissemination of agrometeorology information/products and implementation of precision farming activities requires a multidisciplinary approach (Seeley, 1994; Stigter, 2006). Integration of agrometeorological information with local knowledge on weather forecasting and climate prediction may improve adaptation strategies and ensure that new information, products and services are implemented at farm level.

Farming communities are challenged by incidence of natural disasters such as drought, floods, hailstorms, severe frosts and outbreaks of pests and diseases that lead to crop failure and result in food insecurity. Some few examples as occurred in South Africa are the floods that occurred in 1988 and the drought events that were evident in 1997, particularly in the Free State Province (SAWS, 2009). They had a negative impact on food production, as livestock died and crops were seriously damaged. Information on inter- and intra-seasonal variabilities would therefore be essential as guidance to famers to make decisions for improvements to food security and profit to large-scale producers (Blench, 1999). Seasonal forecasting of sufficient skill assists farmers in understanding scenarios to be expected and it guides farmers in making better decisions about whether, when, how, where and what to plant.

To make decisions, resource poor and commercial farmers in this area originally depended on traditional knowledge and experience collected and accumulated over a long period. Traditional knowledge is explained as the information of a group or a community from a particular area based on their environmental understanding, interacting with nature and experiences within their area (Shumba, 1999; Boef, et al., 1993). Seasonal forecasting in indigenous knowledge was culturally conserved and passed on from generation to generation. Agriculturalists and farmers made use of this knowledge in deciding on crop variety, planting dates and coping strategies so as to produce good yields.

These indicators were used to help figure out the atmospheric conditions in a short period of time to forecast rainfall. For example, should farmers recognize a change in behavior and/or movement of cows and calves in the veld, together with accumulating clouds, it could be an indication that rains will fall in a few hours or a day time. It is very critical to understand indigenous knowledge prior to introducing scientific information to farmers (Okoola, 1996), in order to understand the local farming systems and identify gaps in knowledge that need scientifically grounded approaches for sustainable agriculture. This is more urgent now under conditions of a changing climate that may no longer be covered, partly or fully, with that traditional knowledge and understanding. The focus of this chapter is to present traditional methods applied by commercial and poor resource farmers (Table 2.1), identify existing channels of information dissemination and determine how we can integrate traditional and science-based weather forecasting and climate prediction (see section 4.2).

2.2 Selection of Farmers

Qualitative research seemed to be the best research methodology to associate with the farmers. Various participatory tools were used to exchange data with the farmers. Meetings with farmers were held on monthly basis with study groups in the towns of Brandfort, Koffiefontein, Jakobsdal, Sannaspos, Soutpan, and Thaba-Nchu. The surveys were conducted to scrutinize the use of agrometeorological information/products and the existing channels of information dissemination. It appeared that most farmers had no access to agrometeorological information/products, but they utilized traditional climate indicators to forecast rainfall and other climate parameters. The groups of interest were both the resource poor and commercial farmers. The following steps were made for access to the farmers:

- ✓ Step 1. Identification of Extension Officers for selection of target groups in the south-western Free State, to obtain permission to interact with the local producers through extension officers and selection of the target groups.
- ✓ Step 2. Needs analysis in terms of agrometeorological information/products/services, methods of information dissemination and traditional climate predictions of rainfall forecasting through participatory tools and techniques.
- ✓ Step 3. Focus on the existing channels of information and exchange of traditional climate predictions used by the farmers.
- ✓ Step 4. Farmers were informed on different topics related to agrometeorological information/products and sharing of weather/climate information as an alternative and good relationships were built with the farmers.

In meetings with the selected groups of farmers across Modder/Riet catchment, different participatory tools were used. They were used to obtain and exchange information. The participatory tools used were for example key questions, leading questions and buzz questions (Kramer, 2007; Serrat, 2008, Kelman, et al., 2009). They were prepared to create an atmosphere for open discussion where farmers felt comfortable to express their perceptions and experiences. A transect walk was arranged with the farm owners during the on-farm visits, to view the status of agricultural practices on-farm (Collier, et al., 2006). Research data was collected from individual farmers during on-farm visits. The data was collected using participatory tools and techniques such as focus group discussions during monthly meetings and questionnaires (Zhu and Dale, 2000). Key informants such as extension officers and particular commercial and resource poor farmers were identified prior to engaging in the field work.

Inception workshops were held in 2007 across the catchment, to build rapport with the farmers and to deliver different types of agrometeorological information/products and learn on farming systems from different farmers. In total 394 farmers participated in our workshop, of which just over 10% confirmed that they had access to agrometeorological and other science based information/products and just below 90% mentioned that they depended on traditional climate predictions and/or their own experience to make decisions (be aware that Table 2.3 refer to another population of only 100 farmers). As the workshops continued in different selected areas, the number of participants in the area of original declined to approximately 280 participants due to research funds constraints and lack of interest with some farmers to attend workshops, indicating that they had commitments on their farm. But through awareness campaigns on the application of agrometeorological information invitations were obtained from extension agents and the number of participants and study groups were added. The workshops and meetings with the farmers continued until 2012. A group of 130 farmers were then randomly selected and requested to complete a questionnaire to get the farmers perception on agrometeorological information/products.

2.3 Understanding and differentiation of local farming systems

Farming takes into account conditions such as the amount, distribution and reliability of rainfall, soil type and topography, together with the economic circumstances. Farming systems ideally designate a set of agricultural activities organized while preserving land productivity and environmental quality and maintaining desirable levels of biological diversity and ecological stability (FAO, 2001). Farming systems also refer to a group/combination of agricultural enterprises practiced by the farmers to produce agricultural products, whether for household consumption or for selling to generate income or for both. Many farmers in the south-western Free State have a general similarity in crop and livestock production practices and methods of production. Farmers view their farms, whether resource poor or commercial, as a system in its own right. An individual farm unit is unique, arising from resource support and family background.

The farmers under this study were from different background in terms of resources and support from institutions. The agricultural enterprises identified in this area were fruit trees, vegetables, grain and livestock (small and large). Some farms were owned by a group of beneficiaries that benefited from the Land Redistribution for Agricultural Development (LRAD), others were individually owned, family owned, governmentally owned (leased farms) and inherited by farm owners. Each farm is headed by elders in a group or family to guide and indicate which agricultural activities are suitable for the season. From the survey it was established that farmers mostly produce under rain-fed conditions although farmers near the inland waterways use irrigation systems for crop production. After the realization that most farmers across the study area had no access to science based rainfall forecast products, interest to learn from farmers and their livelihood systems emerged.

At meetings with the farmers, stakeholders from different sectors were invited to come and inform the farmers on their role in the community, e.g. fire fighters, bank representatives, food processors, animal producers, members of agricultural unions and successful commercial farmers. The discussions were very stimulating, especially as 70% of participants were elders. Participant's attendance during the study increased as they realized that they could receive useful knowledge and information produced with scientific methods as well as discuss their traditional climate predictions and experiences. Other towns were also interested as they realized the importance of agrometeorological information.

As already indicated, weather/climate information/products were available to commercial farmers but resource poor farmers had no access to science based forecasts or any other products. However, the commercial farmers also use traditional indicators for rainfall forecasting, although they depend mostly on science based information. From the focus group discussions and transect walks that took place during the diagnostic phase, it became known that science based agrometeorological information/products are not popular with those just below 90% of farmers that had no access to such information/products. After identifying various difficulties confronted by the farmers to be successful in agricultural business, it became a priority to introduce different types of weather forecasting and climate prediction information to the farmers as well as other agrometeorological advisories. Having understood that there was no support service to provide climate related information to most farmers; it was made a priority to set topics that were discussed with the farmers related to useful available science based information/products for improved decision making and management practices. However, the science-based forecasts are difficult to interpret and to incorporate into decision making by both commercial and resource poor farmers. Such weather and climate information as broadcasted on a daily basis on radio and television are not sufficient to guide farmers in strategic long-term planning. But this information may be sufficient to decide on tactical planning if it would be better geared to agricultural use.

In the south-western Free State farmers practice mixed farming systems with crop, livestock production and agroforestry. Farmers that responded to early questionnaires had no exposure to science based weather forecasting and climate prediction, and they developed decisions for farming guided by traditional climate indicators to predict rainfall and other climatic parameters. Therefore, this study explored how the farmers use which traditional climate indicators for short-term and long-term planning for the rainy season. The lack of these signals, at times when expected well in advance, is a weakness and can be seen as unreliable. Moreover there were no signals mentioned that indicated when to expect a poor rainy season. However, farmers are faced with lots of challenges and have to adapt under (increasing) climate variability. The most common and threatening weather and climate hazards are floods, drought, strong dry winds, black frost and hailstorms. The lack of skill to select suitable planting dates for the coming growing season and a wrong interpretation of traditional forecasts have adverse impacts, resulting in food insecurity, starvation, malnutrition and hunger. For example, floods may be due to overflowing of dams and river banks, causing damages to field crops by causing water logging. Early frost could destroy flowers on fruit trees and early planted vegetable seedlings and reduce crop quality. Strong winds could result in loss of livestock and cause soil erosion. For such calamities there were no traditional predictions mentioned so science-based ones are needed.

Farmers surveyed who have been farming for more than 40 years in the south-western Free State recalled the floods of 1987/1988 and 1995 and it was confirmed to be due to La Niña periods. They also recalled the droughts that occurred in 1983, 1997/8 and 2002, which were recorded as due to El Niño periods. Regrettably, when farmers were requested to share the indicators that appeared prior to these events, no forewarnings were recollected by the farmers interviewed. They could only tell of when the events occurred. Also from science long-term rainfall data, for example the floods that occurred in South Africa in 1975, 1987, 1988, 1995 and 2001 seasons, the droughts that occurred in South Africa in 1963, 1979, 1983, 1997,1998 and 2002 seasons, elderly participants could recall years which had extremes. But as already indicated above, from the long-term traditional climate prediction indicators for such events farmers could not mention any. Therefore, traditional climate indicators for rainfall and seasonal rainfall seem to provide only short-term forecasts, at least as far as disastrous years are concerned. Provision of forecasts of sufficient scientific skill at a suitable lead-time to farmers who have no access to science-based information could assist farmers to prepare for and minimize adverse effects. During such harsh events, farmers would be able to minimize the impact by making adjustments according to the forecasted events. For example during a well forecasted drought season the farmers could use drought tolerant crops or early maturing varieties and other intervention strategies as necessary. Integration of scientific and traditional climate prediction could be useful to augment and improve on-farm decision making strategies, considering that farmers operate on different perceptions and farm scales. Therefore, verification of traditional rainfall and seasonal forecasts (a kind of calibration that we also apply to scientific information) becomes a point of interest to try to investigate how traditional climate indicators work out as seasonal climate predictors in the south-western Free State.

2.4 Traditional climate predictions and other traditional weather/climate information

Traditional rainfall forecasting refers to indicators that are used by a specific group of people in a particular kind of environment to interpret weather/climate conditions. Traditional rainfall forecasts/predictions differ across communities, cultural background, and environment around the farm (Casta Neto, 2006). For example, in south-western Free State, Kwa-Zulu Natal and Western Kenya, inhabitants use birds, toads and white ants to predict the summer season and onset of rains and temperatures ranging from 18°C to 26°C (Merchant et al., 1987; Olbrich and King, 2003). While in the north-eastern Brazil they use the appearance of crickets. In Tanzania, they look at the behavioral patterns of birds and mammals (Prendergast et al., 1999). According to Dunn (2000) and Kihupi et al., (2003) arthropods, namely flea, cockroach, housefly, spider and many others are synonymous with the summer season in Japan and even the name of invertebrates are figuratively synonymous of a particular season. These arthropods have been noticed by farmers to be abundance during the summer season for example farmers stated that cockroaches disappear during winter season. Traditional climate prediction and contemporary seasonal forecasts were thought to be useful and dependable by resource poor and commercial farmers (Kihupi et al., 2003). Nevertheless, due to increasing variability in climate, most farmers are keen to train on the applicability of science-based information/products for farm decision making (Leibenstein and van Marrewijk, 2000).

Before the systematic of Table 2.1, just a few loose examples. Vegetable farmers in Lejweleputswa district, Brandfort town, observe the sprouting of aloe plants and blooming of peach trees as indicators of the beginning of the rainy season, so farmers should prepare land to plant immediately after rain water has infiltrated into the soil. See also Table 2.1. Of course, in higher areas, if such blossoming is followed by rain, frost possibilities have diminished, unless it is a false start of the rainy season. Farmers in Motheo district, at Sannaspos, observe the behavior of livestock. If well-fed calves are playing around at the grazing field, it is interpreted as that the rains will come in 2-3 days (Mr. Mahlangu, private communication, July 2007). In Jakobsdal and Koffiefontein area, observation of the movements of snakes and tortoises is interpreted as the coming of good rainfall as a seasonal forecast (Mr. Mokhele, private communication, January, 2009). This corresponded with the 14 days weather forecast, as it gave 60-80% probability of receiving greater than 1mm of rainfall from the 7^{th} -13^{th} February 2008. However, this might well be incidental because 14 days forecasts are notoriously unreliable (Gardner, 2010). For season 2008/2009, Mr Cilliers from Phillipolis (private communication, see Box 2.1), noticed that the snakes and tortoises were busy in the veld and predicted that good rains were to come. It came to pass and in celebration he cut his beard of 27 years. The above normal blossoming time of peach trees, apricot trees (Mr. Martins, August 2008, Soutpan, private communication) and other trees in the south-western Free State, as occurred in September 2008 and 2009, was used by farmers to predict a good rainy season (see also Table 2.1) and it also came to pass. It turned out that both seasons, 2008/2009 and 2009/2010, received good rains in this area. The appearance of plants and cloud types are the factors that appeared to be most favored by farmers. For instance, the sprouting of a variety of plants including Aloe (*Aloe ferox*), peach trees (*Prunus persia*), apricot trees (*Prunus armeniaca*) and the shedding of leaves of the fig tree (*Ficus carica*) indicate the beginning of the planting season (Table 2. 1).

1.4.1 Indigenous knowledge for rainfall forecasting

More systematically, the farmers, during meetings, focus group discussion and transect walks listed various traditional climate indicators for rainfall forecasting. The indicators ranged from shape of the moon, wind speed and direction, star patterns, cloud formation, to the earlier mentioned plant characteristics and animal behavior. Indicators based on plant characteristics seemed to be the most favored and important to the farmers and the least important were the water sources (Table 2.1).

Table 2.1 Traditional climate prediction indicators and its use to interpret rainfall conditions.

Indicator	*Indication for weather occurrence*	*Time of occurrence*	*Activity to do or action to take*
Appearance of plant	◦ *Blossoming of fruit trees above normal like peach (Prunus persica), apricot (Prunus armeniaca), budding of acacia spp., and other ornamental trees in the farm surroundings and development of young leaves, grass emerging, sprouting of Aloe ferox in the mountains are indications of good rains*	*September*	*Spring season, prepare for sowing in November (general knowledge all groups).*
	• *Flowering of wild lilies in the veld indicates summer*	*September*	
	• *Dropping of fruits before maturity indicates very dry season or drought season*	*September/October*	
	• *Dropping of leaves of fig tree (Ficus carica) indicates summer*	*September*	
	• *Immature fruits drying on trees and/or dropping from the trees is an indication of drought*	*September/October*	*Farmers should consider drought tolerant crops and short cultivar varieties (Mr. Martins, Soutpan)*
Months of the year	• *July to forecast for first rains that moisten the soil,*	*July*	*After rains the land can be ripped*
	August rains	*August*	*The soil is ready to be turned over to minimize weeds.*
	Dark clouds indicates rainfall	*September-March*	*Sowing/rainfall season (general knowledge all groups)*
Clouds	• *Dark clouds are an indication of heavy rainfalls to occur within a few hours* • *dark clouds preceding strong winds indicates thunderstorms in few hours* • *Rainbow colours: red dominating means more rains to come, if blue color dominates and clear sky appears it means that rain has passed.*	*Throughout the season*	*Always be prepared to minimize damages that might occur due to heavy rains and arrange for roof water harvesting to be stored for use as irrigation is needed (general knowledge all groups).*
Cloud types	*Stratus cloud is a sign for cold days*	*June, July*	*Prepare for extreme cold conditions (general knowledge all groups)*
Soil structure and its dryness	*Soil well moistened tested by hand*	*October-December*	*Introduce seeds or seedlings under wet watered soils*
	Soil not well moistened	*October-December*	*Wait for rainfall onset (Mr. Mokhethi, Sannaspos)*
Appearance of various insects	• *Appearance of red ants and rapidly increasing size of anthills which are moist is used to predict good rains* • *Occurrence of army worms is an*	*November/December*	*Prepare for sowing season*

	indication of drought		
		Mid-April, July and early August	*Prepare for drought season (general knowledge all groups)*
Birds	• *First appearance of sparrows* • *Flock of swallows proceeding dark clouds* • *Migration and immigration of birds good sign of rainfall*	*October-March*	*Rainy season is at hand, farmers should prepare for planting and act to minimize risk and disaster that might result from above normal rains (general knowledge all groups)*
Moon phases	• *Moon crescent facing upwards indicates upholding water and when facing downwards is releasing rainfall in next three days* • *moon surrounded by moisture (halo profusion) means good rains* • *First rains should occur before the appearance of the new moon and then full moon covered by the clouds indicates good rains*	*October-March* *September/November* *October/November*	*Planting time for vegetables and cash crops suitable for the area, farmer should follow moon phases as control to the days with and without rainfall (Mr. Mpinga, Bloemfontein)*
Star constellation	• *Star pattern and the movement of stars from west to east at night under clear skies, indicate onset of rainfall in 3 days and patterns also used to predict cessation of rainfall*	*August-November*	*Prepare the land and buy inputs to plant as it is the rainy season, select suitable days, cultivar and crops to plant (Mr. Mahlangu, Koffiefontein)*
Animal behavior of domestic animals	• *Grunting of pigs indicates low humidity and increase in temperature* • *Well-fed calves jumping around happily in the veld and on their way home from grazing in the mountains and unwilling to graze the following morning indicates good rains on the way* • *Increased libido in goats and sheep with frequent mating is a sign for good rains*	*October to March* *Throughout the season* *August, September, October*	*Prepare for agricultural activities (general knowledge all groups)*
Appearance of reptiles	• *Certain snakes moving down the mountain sign of good rains* • *Frequent appearance of tortoises wandering around indicates that we should get good rains*	*August, September* *September-November*	*Prepare for growing season with good rains (Mr. Venter, Jacobsdal)*

Wind swirls	*High frequency in occurrence of wind swirls is a sign for good rains*	*October/November*	*Farmers should prepare and plant since good rains are predicted (Mr. Ncangiso, Sannaspos)*
Wind direction	*Early in the morning changing direction from W-E signal good rains*	*November-March*	*Prepare and plan ahead for rains to come (general knowledge all groups)*
Mist covering hills and mountains	*This is a signal for good rains to come*	*Throughout the season*	*Ensure that when rain comes the crops are already planted and developing. (general knowledge all groups)*
Atmospheric temperature	*High temperature at night is a sign for good rains and a long crop growing season, low temperatures at night is an indication for late onset of rains and late planting season*	*September-November*	*Farmers plan on when to plant and crop types of a season to expect (Brandfort group)*
Water sources	*Drying up of wells, springs, river and wetlands rapidly is an indication of good rains*	*Spring*	*Farmers could prepare for a good rainy season and plan their activities in advance (Mr Molelle, Sannaspos)*

2.4.2 Comparison of knowledge systems

The traditional prediction and science-based products on rainfall climate forecasting differ as they operate at different scale and use different methods. Meteorological indicators like wind patterns, temperature, clouds, they are interpreted the same for a certain locality. For example, north-westerly winds in southern Africa bring moisture from the Tropical Atlantic Ocean and that condenses to produce precipitation. The scientific forecasts in South Africa are generated at a large geographic scale, i.e. something like 200 km, they are provided with various degrees of skill at a lead-time of 6 hours, 7 days (already very risky (of low skill)), 14 days (not common elsewhere because of very low skill), a month, a season (say three months, with much lower skill) and up to six months (very risky and not common elsewhere because of low skill). However, traditional climate predictions provide forecasts only for rainfall and usually at a relatively short time scale. This lowers the usefulness as there is often little provision of sufficient lead time to prepare to reduce destruction and/or disseminate it widely to make proper farming decisions. Scientific forecasts/predictions in South Africa provide among others indications with varying skills of the probability of receiving more than a specified amount of rainfall. For example, the 14-days prediction (at low skill, e.g. Gardner, 2010) presents the probabilities of receiving > 20 mm; > 5 mm (Fig. 2.1) and > 1 mm (Fig. 2.2 and see Appendix 1.7 (a) and (b)) of rainfall.

Box 2.1 **February 2008**

For example, the traditional rainfall forecasting provided by Mr. Danie Cilliers alerted the farmers on good rains to come. He advised commercial farmers, backyard gardeners and resource poor farmers to go back to the fields and plant vegetables, grain crops in high population densities since lots of rain were expected. His forecast was stated as follows (and I quote):
"Springboks are lambing well, snakes and tortoises are active and there was a full moon, which means lots of rain for Philippolis and the rest of southern Free State." Mr. Danie Cilliers Farmers weekly, 13 February 2008.

The 14-days rainfall prediction during February, 2008 indicated the probability range from 60%-80% of rainfall greater than 1mm (Fig. 2.1) and 40%-60% of receiving rainfall greater than 5mm (Fig. 2.2) for different days. This is an indication that these two methods could to a certain extent complement each other, because both talk about probabilities, one qualitatively and the other (semi-)quantitatively, but this still needs to be validated in future studies.

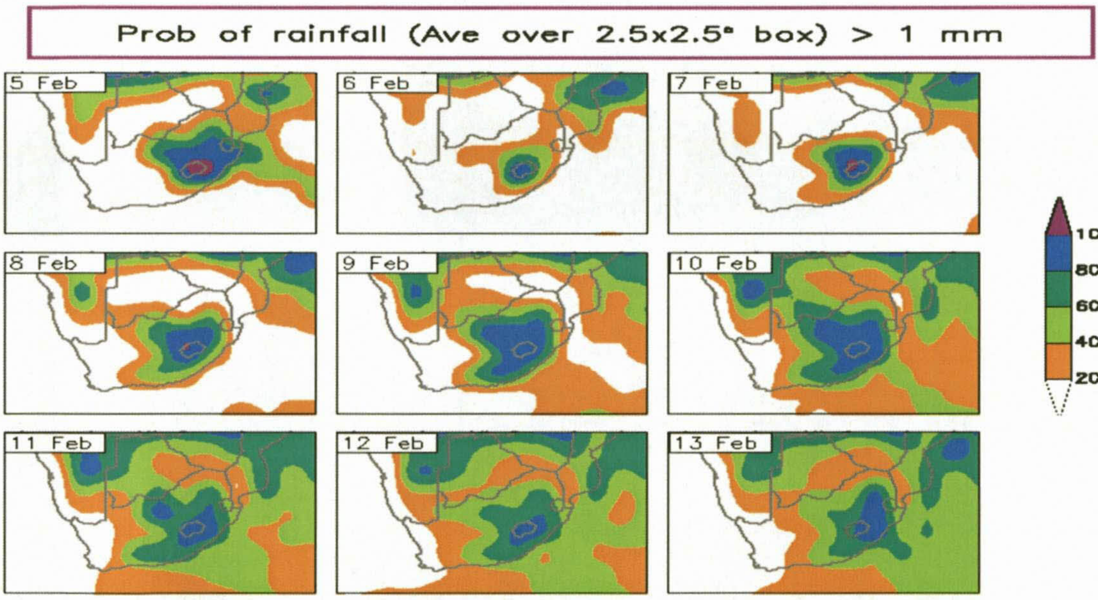

Fig. 2.1 14-days rainfall prediction for receiving > 1 mm for southern Africa for nine specific days in February 2008 (SAWS, 2008) this forecast was issued on 30th January.

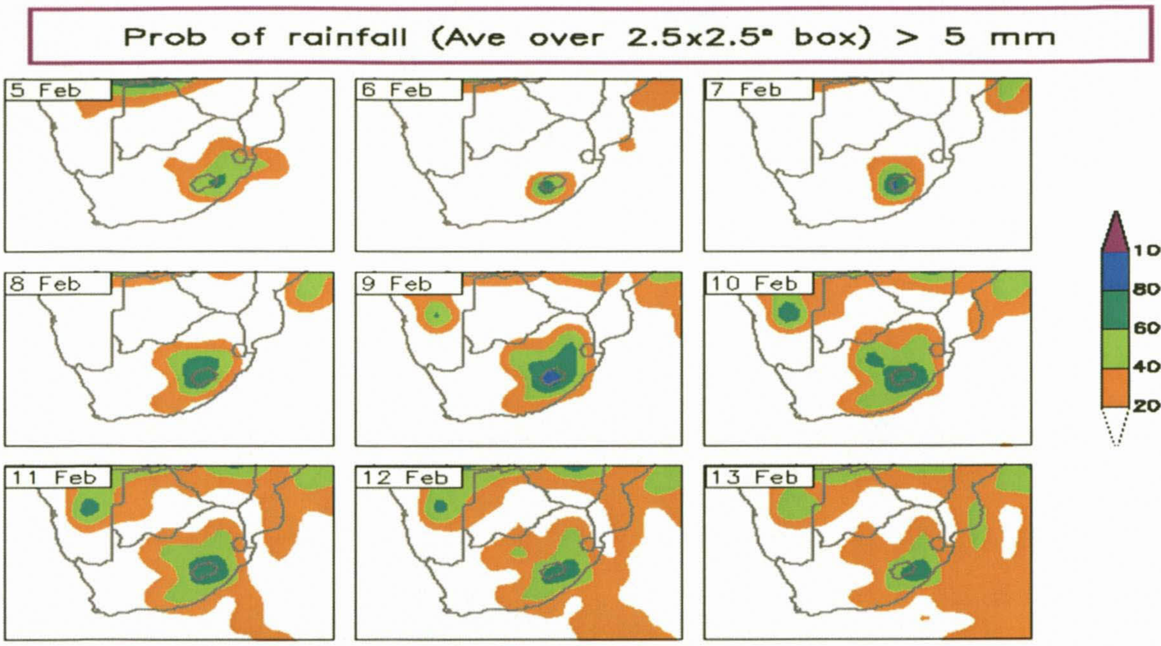

Fig. 2.2 14-day rainfall prediction for receiving > 5 mm for southern Africa for the same nine specific days in February 2008 as in Fig. 2.1 (SAWS, 2008)

The seasonal forecast for 2008 (Table 2.2) indicated slightly less chance of above normal than normal or below normal rainfall for August till November inclusive and a somewhat better chance for above normal rainfall when December was included (with of course a lower skill!) but still less chance than the normal and the below normal combined. At the monthly meetings with the farmers, the forecasts were communicated one-two months in advance in this probabilistic manner along with an advisory for the specified season (Appendix 1.7). The initial advisory recommended two planting dates: 15th November 2008 for farmers with irrigation schemes and last week of December 2008 for rain-fed farmers.

Table 2.2. Rainfall forecast for southern Free State from August to December 2008 issued July (SAWS, 2008).derived from Fig 2.3.

Probabilities	ASO (%)	SON (%)	OND (%)
Above-normal	40	40	45
Normal	27	27	33
Below-normal	33	33	22

This information should in fact guide the farmers to make tactical and operational strategic decisions from the initial agricultural activities, such as land preparation or tillage, planting, weeding, fertilizer application, to insecticides application, frost preventative measures, harvesting and crop storage. If of high skills, the predictions may guide farmer decisions throughout the planting season until harvesting and storage. Whereas weather/climate forecasting using traditional climate prediction only allows the farmers to make decisions in terms of possible rainfall onset using indicators such as the moon phases, wind direction and intensity before the planting season. However they could be complementary this way.

During 2008/2009 farmers argued about the reliability of the forecast and decided to wait and witness what happened, while using the traditional climate prediction, observing the clouds, types of insects, wind patterns. When in the first week of January the farmers observed a swarm of swallows flying around, they confirmed that it was the month to receive rainfall. They also observed the westerly that occurred blowing early in the morning and witnessed that rainfall was to come within a few days and rainfall was experienced during the first two weeks of January. Another example is presented in Box 2.2 and Fig. 2.4, where the farmer predicted cold conditions and lower chances of receiving rains by just observing the cloud types. This observation and experience is also a good indication that there is a possibility to bridge the two different knowledge systems. Maybe there are some of the traditional climate predictions that hold comparable interpretations as scientific variables used for rainfall and temperature forecast. The downscaled weather forecast products for the Modder/Riet catchment were obtained from the University of the Free State (Steyn, 2009 private communication).

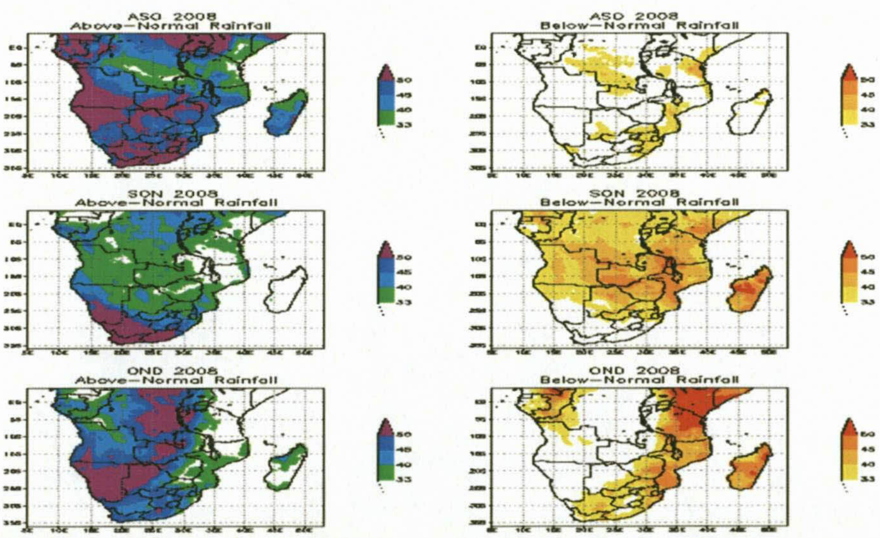

Fig. 2.3 Three monthly rainfall prediction probabilistic map for southern Africa for August to December inclusive (SAWS, 2008). This delivered Table 2.2 for the southern Free State.

Box 2.2 **August 2009**

Mponeng Lentoro, a female farmer from Bainsvlei, had had no access to forecasts produced by SAWS. She strongly believed in and relied on indigenous forecasting methods. On 18 August 2009 her weather prediction was that it was going to be colder, as she saw thin lined dark (stratus) clouds in the sky. She mentioned that it was going to be colder and with less rain. The science-based forecast showed similar conditions and 30 % chance of rainfall and it was very cold in Bloemfontein that day. The minimum temperature was 3ºC and maximum 8 ºC (SAWS). So it means that her short-term forecast with indigenous knowledge was good and correct.

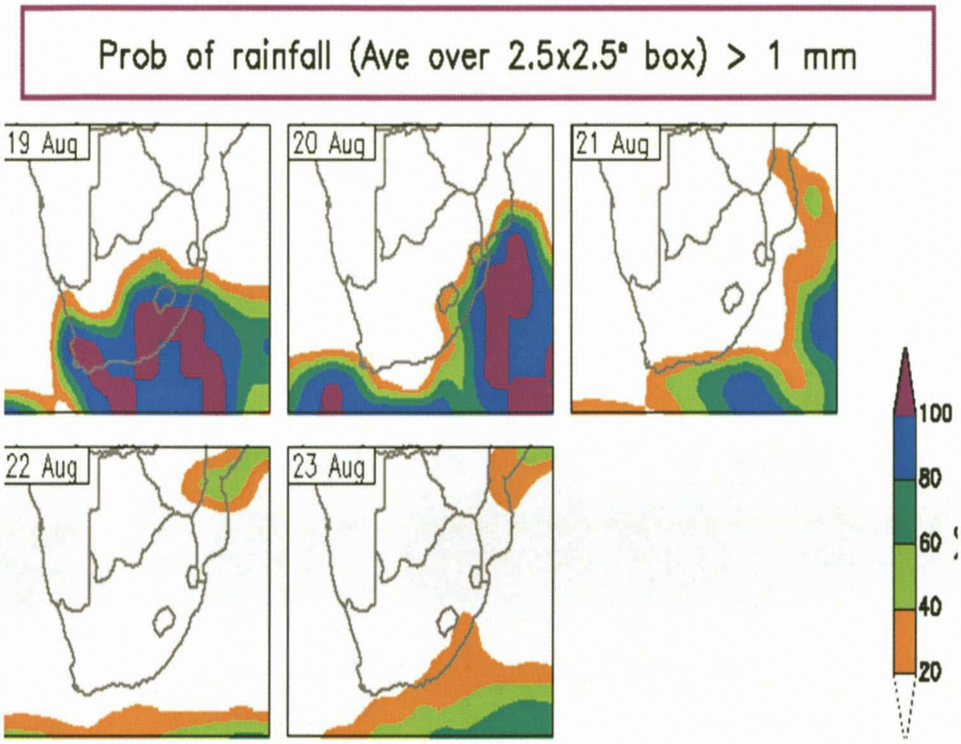

Fig. 2.4 day rainfall probabilities predictions for amounts larger than 1 mm for southern Africa for August 2009 (SAWS, 2009).issued 9August. The rains were experienced on the 19 of August in the afternoon.

The traditional forecasters in all study groups were put to test in October 2009. They were requested to predict rainfall and mention which day or week it should be expected. They were requested to communicate the indicators to the researcher before the rain came, via cell phone Short Message System (SMS). The participating farmers followed the instructions and the outcomes were that all participants predicted the rainfall for the second week of October 2009. This was compared to the 14 days forecast with a probability of 80%-100% of rainfall more than 5 mm, from the 10th -12th October 2009, as shown in Fig. 2.5 for SW Free State. During this period in October, 15 to 25 mm of rains was indeed received in three days. This means that both forecasts were successful and complementary, the one on the start of the rains and the other on the amounts to be expected. The indicators that were mentioned by farmers were, in line with Table 2.1, busy reptiles in the veld, westerly winds at night, accumulation of dark clouds, flocking of swallows flying around and the smell of rain. It was indeed also interesting to know that farmers claimed that they could smell the coming of rains a day to a week before the rains actually come. As much as some scientific rainfall forecasters perceive the traditional climate prediction indicators a myth (Landman, 2008, personal communication), the traditional forecasters strongly believe that scientific forecasters are not accurate for their purposes. We have above proven this scientist wrong as have others before (e.g. Stigter, 2010) while farmers will get to appreciate skilled seasonal climate predictions, and we will more and more see these actual skills mentioned with forecasts and predictions given to explain uncertainties (e.g. Ramirez-Villegas and Challinor, 2012).

Observation as the project progressed was that farmers got more interested to learn about the weather/climate products and their usability for agricultural applications. For example, some farmers called researchers to be updated on the seasonal conditions on a weekly basis and a few farmers (for example, Mr. Cangiso, Mr. Scotts and Mr. Mokhethi, October, 2010) even made initiatives to have access to e-mail in order to receive weather bulletins for planning before the season. For example the Ladybrand group sent their chairperson to request the frost chart for them to identify the frost free dates as they intended to produce tomatoes (November, 2010).

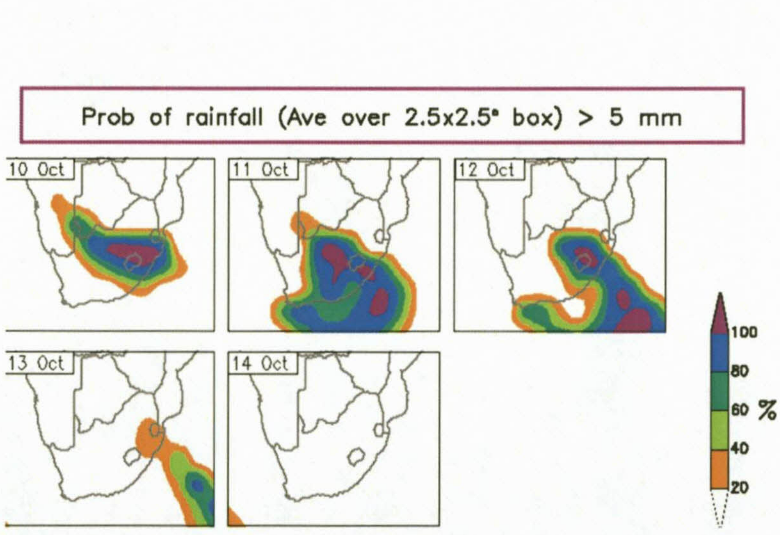

Fig. 2.5. 14 day rainfall probability for southern Africa October 2009 issue date 30 September.

2.4.3 Disadvantages and advantages according to farmers

For the farmers to learn on and confidently adapt science-based information, they were tasked to list the advantages and disadvantages of using traditional climate prediction indicators. It appeared that this exercise was not the easiest, as it raised lots of disagreement amongst the farmers. This lead to different opinions from different experiences. Eventually, the farmers were able to draw some conclusions regarding this matter. They listed and identified the following statements as disadvantages of traditional climate prediction indicators:

- ✓ it is only momentary but it can work well when combined with scientific forecasts/predictions,
- ✓ it is culture-based and interpreted differently for different areas,
- ✓ it does not provide predictions on the not immediate future,
- ✓ it cannot predict mid-season dry spells or their probabilities,
- ✓ it does not indicate rainfall distributions but only when to prepare for the onset,
- ✓ it is not trusted by some scientific forecast producers as they, incorrectly, perceive it as based on superstition.

As disadvantages with regard to the scientific forecasts/predictions, the farmers mentioned that:

- ✓ it is not easily available and accessible,
- ✓ it is difficult to interpret and to make decisions based on the probabilistic information given,
- ✓ it is not point specific as it only covers big areas, not villages or farm scale locations.

The best outcome of this study was that farmers learnt new things and shared their information and experience. Through the process of interacting with other farmers, farmers learnt and steadily adapted the application of weather/climate information/products and other science-based agrometeorological information for agricultural decision-making.

2.4.4 Substantiation of traditional climate prediction indicators

The interest taken in traditional forecasting, summaries are given on the most important indicators.

2.4.4.1 Utilization of the months of the year

Farmers traditionally depend on the months of the year to determine the agricultural activities to implement. The months are even named after the agricultural conditions and certain meteorological parameters. For example, the last week of July in the south-western Free State is well-known to bring first rains according to Mr. Chamare of Sannaspos, but the mean monthly rainfall shows that the agricultural onset of rains is only experienced in September, as above 25 mm of rains should be expected per month. Farmers say that the July rains are critical to moisten the soil cause decay of residues on the fields and are an indication of the start of the season, in the sense that they should prepare tractors for land preparation. These observations are correct from a farming point of view! August symbolizes the month for first plowing to occur which is aimed at turning over the soil to minimize the spread of weeds and insects.

Mrs. Nikelo who is a resource poor farmer, emphasized that months of the year are the main indicators for the planting season. Commercial farmers in the south-western Free State were observed to cultivate the land in late July and after the August rains in 2008 and 2009, in line with the traditional farming. Farmers plow the fields and then wait for September rains to transplant seedlings obtained from local nurseries or produced from on-farm under plastic tunnels those who do not plant vegetables will disc the land to prepare for November planting of maize, sunflower and sorghum. The list of weather station data in the south-western Free State indicates that the mean monthly rainfall greater than 25 mm starts in September and increases while it reaches a peak of about 80 mm in January and decreases to about 40 mm in April. Therefore, months of the year as a general traditional climate prediction indicator to forecast rainfall are backed by scientific observations. But they were more so before climate change started to make its impacts (e.g. Stigter, 2010).

2.4.4.2 Soil wetness after rainfall

The farmers use the amount of water in the soil: as it makes a ball, it means that there is sufficient water in the soil. If the soil does not have sufficient water, it crumbles and falls apart. This is a method used to test the wetness of the soil by, among others, Mr. Mokhethi. He mentioned that he does not know of any other methods that he can adopt as an alternative. When soil is saturated, all air spaces are full of water, but as the gravitational water drains out, the soil reaches field capacity, where plants are able to draw water till wilting point is reached. It is near field capacity when the soil forms a ball without water being squeezed out.

2.4.4.3 Plants

The budding of fruit trees is associated with the onset of spring and summer season, which is a planting season for summer crops. Emerging and growing of new leaves from different types of trees in the vicinity are a good indication that temperatures are increasing and the winter season is over. Summer is dominated by the mean monthly temperature of 20°C and monthly rainfall above 20 mm. The types of grass and shrubs in the veld that have developed new leaves emerging symbolize the beginning of the planting season. One of the most prominent indicators of summer season is the sprouting of the *Aloe ferox* plant decorating its orange flowers over the hills (Mrs. Nikelo). For example, all four study groups identified *Aloe ferox* as an indicator for the beginning of the planting season. *Aloe ferox* in the south-western Free State is actually not flowering until September due to colder conditions whereas flowering in warmer areas is known to occur between May and August (Glen & Hardy, 2000). *Aloe ferox* is adaptable to many conditions. It means that such traditional forecasting will keep much of its validity also under conditions of a changing climate (Stigter. 2010).

Peach trees (*Prunus persica*) require mean temperatures in summer of 20-30°C. Peach trees bloom in early spring and any drop in temperature below 14°C after flowering tends to kill the blooming flowers (Naik, 2010). Flower buds get destroyed between -15 and -25°C. Spring frost can be a limiting factor and minimize fruit production (Gradziel and McCoa, 2008.). Farmers therefore associate the flowering of peach with the beginning of planting season. Apricot trees (*Prunus armeriaca*) are hardier, less frost sensitive, tolerating winter temperature to -30°C (Naik, 2010). They flower very early in spring (August to September for south-western Free State) since they have a chilling requirement.

Another example used by the farmers is the fig tree. Fig trees (*Ficus carica* L.) have a cold hardiness temperature of -2.2 to -6.7°C. The mean suitable temperature is about 18°C for budding and flower development (Piga, et al., 2004). t. Fig trees flower from spring to autumn depending on the tree variety.

The types of trees mentioned above require a certain amount of low temperatures to hasten plant development and flowering (Naik, 2010). The trees have to go through a vernalization period to break dormancy (Michael et al., 2003; Chouard, 1960). Therefore, low temperatures that occur in July, August and September play a critical role to initiate the development of buds on trees that results in flowering. Should low temperatures occur when trees have blossomed, this might result in flower and fruit damages due to cold conditions (Amasino, 2005). After the trees have flowered, warm temperatures are required to provide thermal time (certain amounts of temperature in degree days) for tree and fruit development throughout the developmental stages until harvesting of fruits. Farmers observe these changes in plant stages and use the appearance of leaves to predict the planting season.

2.4.4.4 Animal and bird behavior

Farmers use the appearance of Mossies or Cape Sparrows (*Passer melanurus*) as an indication of good rains to come in a day or two. It serves as a decision point that they should prepare for field activities (de Swardt et al., 2004). A flock of sparrows flying around the sky with scattered clouds indicates that there is rain coming in the afternoon. Heavy migration of flocks merging into widespread structures is a resemblance for weather echoes (Eastwood, 1967, Koistinen, 2000). The occurrence of a heavy flock of birds flying together indicates the wind conditions that could be fatal, e.g. convergence (Koistinen, 2000). A flock of sparrows leading dark clouds indicates heavy rainfall within approximately an hour. Migration of certain bird species is associated with change of the season in terms of temperature and rainfall (de Swardt, 1995, Koistinen, 2000; Kopij, 2002). According to Anderson and Erikson (2006), the appearance of birds and insects could assist in detecting meso-scale meteorological phenomena such as gust fronts. Flocks of sparrows are observed in the south-western Free State during the growing season, as they also feed on seeds and insects.

As earlier noted, livestock owners in Brandfort reported that when well fed calves are seen jumping around in the veld, this is an indication of rains to come. If the herd of cattle is noticed hesitant to go to the veld for grazing, it shows that the rains are to come within a few hours. Other farmers mentioned that cows in the field lie down (Berkeley & Linklater, 2010) when the rain is on its way within a few hours. Whether the calves are sensitive to low pressure systems, high humidities or changes in temperature, is not yet well known (Changa, et al., 2010). Research on this influence of climatic parameters on calve behavior in Modder/Riet catchment would be helpful, to verify why farmers observe it to forecast rains. Finding scientific reasons for traditional believes is advisable throughout (Stigter, 2010).

Certain snakes moving down the mountains means the season is getting warm. This statement was made by commercial farmers in Jacobsdal in a meeting held in October 2007. The farmers mentioned that snake activity increases in two seasons of the year, in spring and summer. The snakes come out of hibernation and down the mountains in search for prey and mating partners to reproduce. In the early summer season the eggs hatch and baby snakes are produced and fatten their bodies in preparation for the cold season at hibernation (Branch and Branch, 1998). For example the Rinkhal in greater Bloemfontein appears during spring and early summer and it lives in grassland (Marais, 2007). Farmers become cautious when the snakes are seen more often hunting for prey, because it is an indication of the onset of the growing season.

2.4.4.5 Moon phases and star constellation

Farmers across the south-western Free State mentioned the use of the appearance of the crescent of the moon facing up as a traditional rainfall indicator, which is explained as follows.

If the crescent appears facing upwards, it is an indication that it can hold rainfall, and immediately as the crescent appears face down, it is an indication of releasing rainfall to mother earth and rainfall should be expected within three days. Farmers across the region commented that good chances of rainfall are expected around the date of the new moon and that in contrast full moon is usually associated with lower rainfall chances. If a poor rain event occurs at the time of the new moon, the following months are expected to be dry. Good rains at new moon indicate that the following month will be wet. Farmers have used moon phases for planting decisions for decades. The waxing of the moon is the recommended time to plant leafy vegetables and flowers, transplant seedlings. The waning of the moon is an indication to plant underground crops, e.g. potatoes, sweet potatoes, groundnuts, control weeds and thin the plants (Crawford, 1989; O'mahony, 2006).

Farmers also mentioned the techniques of using star patterns and movement to predict rainfall onset, days to expect rainfall and rainfall cessation. However, the farmers could not explain exactly how it works. As the moon phases and its orbit around the earth affect the rising and falling tides, air currents and the occurrence of thunderstorms (Crawford, 1989), it could be observed that this indigenous knowledge is related to scientific logic. Whether the use of moon phases and star constellation has a relationship to rainfall or not, farmers in the south-western Free State are confident that it works well as a predictive tool for rainfall and the agricultural activities to consider for different seasonal conditions. Here again scientific research would be helpful, particularly while climate change may influence any of these relationships (Winarto and Stigter, 2011).

2.4.4.6 Insects appearance

Seasonal variations in insect population have been studied and showed that the insect population varies throughout the seasons of the year (Lowman, 2006; Changa, et al., 2010). Therefore, given this background, the appearance of ants and mushrooming of anthills occur in the planting season in the south-western Free State. It is for this reason that farmers observe different insects to predict the rainy season. It for example means that the daily temperatures are warm enough for the ants to come out from hibernation and roam around the soil. And thus it is also warm enough to plant crops that are sensitive to low temperatures.

2.4.4.7 Clouds, wind and temperature

Dark cloud appearance is well known as an indicator for good rains coming within a few hours. As the moist air rises in up draught into the atmosphere and cools, the water droplets collide until it produces raindrops that fall from the clouds to the ground. Rain clouds are large and grey, and because of the high density of water in clouds they appear dark to the human eye. Cumulonimbus clouds can result in heavy rainstorms. Nimbostratus results in slower and steadier rainfall that can last for hours to days. Stratus clouds can result in drizzle. Clouds are used as it corresponds with the scientific information of cloud characteristics as types of clouds resulting in certain types of rainfall. If the cloud appearance is related to the coming of rains, also this traditional climate indicator could be kept to be related to scientific reasoning. For example, even the 14 days predictions (SAWS) represent cloud cover and use probabilities to predict the chances of getting certain amounts of rain. This prediction, however, is in need of a large scale validation study in different parts of South Africa.

Farmers from all study groups reported wind direction as another indicator used to forecast heavy rainfall. Farmers strongly believe in observing the wind direction to predict the onset of rainfall. Farmers use westerly winds to forecast rains within a few days. However, further research to determine more scientific explanations for these indicators would be necessary before they can be introduced with their full scientific information (e.g. Stigter, 2010).

2.5 Existing and recommended channels of information dissemination

2.5.1 Agrometeorological information/products/services in south-western Free State

The south-western Free State covers towns from two districts namely Motheo and Lejweleputswa. Motheo involves large areas of commonage farming with sheep and cattle. The predominant crops planted in this area are vegetables, maize, sunflower and sorghum. Lejweleputswa is also dominated by livestock, vegetables, maize and sunflower production under dryland farming and irrigation (www.fsagric.fs.gov.za).

The Free State Directorate of Agricultural Disaster Risk Management (FS-ADRM) receives advisories from the National ADRM within the Department of Agriculture, Forestry and Fisheries (DAFF) (Motsepe, 2008; Wessels, 2009 private communication). The ADRM unit in the Free State has been established and given the mandate from the presidency for planning and strategically coping with risks to minimize the effects of natural hazards and agricultural disasters. As stipulated according to Act 57 of 2002: Disaster Management Act, the FS-ADRM unit has to provide for (and I quote):

"An integrated and coordinated disaster management policy that focuses on preventing or reducing the risk of disaster, mitigating the severity of disasters, emergency preparedness, rapid and effective response to disasters and post-disaster recovery. The establishment of national, provincial and municipal disaster management centers. Disaster management volunteers, and matters incidental thereto." (www.fsagric.fs.gov.za)

Hence, DAFF through ADRM introduced an Early Warning Committee (EWC) for natural hazards to provide and improve awareness of disasters and agricultural management reducing risks and their consequences. The EWC has to issue accurate and timely information from weather/climate and agrometeorological sources so as to provide a warning to individuals at risk with the intent of minimizing the severity of disaster. However, for the EWC to be effective, according to Act 57 of 2002, it should provide prior risk knowledge, monitoring and warning services, dissemination and communication as well as response capability.

Box 2.3

The response capability was focused on sheltering small stock during hail storms to protect them from injuries that may occur. Frost net under predicted severely frost predictions have been erected by few farmers in the study area. During severe frost forecasts farmers are advised to make fire around apricot trees to increase temperature in Soutpan. During strong winds and dry vegetation fire breaks under are recommendable. Sprinkler irrigation over night to avoid frost occurring on Swiss chard leaves and other vegetables and crops is advisable.

DAFF developed and established the National Agrometeorology Committee (NAC) to plan and put into operation the EWC in support of Act 57 of 2002. NAC comprises relevant directorates within DAFF, relevant universities, the Agricultural Research Council, the CSIR, the South African Weather Service and Disaster Centers within local municipalities. The NAC meets on a quarterly basis to review the seasonal forecasts and to discuss how to assist the farmers in terms of planning for agricultural activities using the forecasts. The advisories developed by this meeting should be of good quality and user friendly prior to dispatch to extension officers and farmers. The NAC advisory is available from the AGIS website: (www.agis.agric.za). The NAC advisory is dispatched from DAFF-ADRM national office to provincial ADRMs. The provincial ADRM transforms these advisories so as to be locally understood, thereafter delivers them to the extension Directorate to be disseminated to the end-users or farmers. This was discussed in the National Agrometeorological Committee held in the Free State province in 2010. According to Wessels (2009 private communication) the

ADRM unit in the Free State provides a monthly report on agricultural conditions. This report also includes climatic conditions, with emphasis on the previous month, such as rainfall conditions, temperature, the Normalized Difference Vegetation Index (NDVI), water supply, veld and livestock conditions. The Provincial DAFF-ADRM and Mangaung Local Municipality (MLM) operate as different entities but with one mandate of fulfilling Act 57 of 2002. Therefore, a close linkage between these two units should be formed. The Provincial Disaster Management Committee (PDMC), which meets on a quarterly basis, constitutes departments from the Free State province, municipalities as well as community members' representatives (Losabe, 2008 private communication). The MLM Disaster Centre receives warnings from SAWS and disseminates them to the community. The most frequent natural disasters in the Free State are high winds, floods, dust-storms, heat waves, hail, veld fires and snow (Losabe, 2008 private communication). For example, snow that occurred on the 7th August 2012 were advised timely to organize feed and shelter livestock. Floods that occurred in 2010 were followed by the outbreak of Rift Valley Fever which claimed a number of livestock, since than farmers are encouraged to vaccinate in time. Maize yield was lessened resulting to heavy rains that occurred during harvesting time and due to wet conditions farmers were not able to harvest timely.

The University of the Free State (UFS), Department of Soil, Crop and Climate Sciences within the Faculty of Natural and Agriculture Sciences, provides undergraduate, post-graduate and short courses on agrometeorology. The courses entail on-farm practical information for decision-making, e.g. analysis of seasonal forecasts, calculation of reference evapotranspiration, irrigation scheduling, fire danger index, pest/diseases outbreaks. The UFS, Disaster Management Training and Education Centre for Africa (DiMTEC), does training and post-graduate education and consultation for disaster risk management. DiMTEC's responsibility is to assist the government in drawing up disaster related policies, develop an advisory issued every two months and post-natural risk assessment. The UFS is one of information developers and this information is not disseminated to the potential end-users but it is shelved.

The Agricultural Research Council - Institute for Soil, Climate and Water (ARC-ISCW) and the South African Weather Service (SAWS) monitor a network of weather stations nationwide. The ARC-ISCW produces disease reports, crop yield estimates, pest outbreak reports, seasonal outlooks and agrometeorological zoning, Umlindi and maintains historical climate databases. Umlindi a newsletter produced by the ARC-ISCW provides information on fire warning, drought monitoring, NDVI, SPI, to be sent to the ministry of agriculture where it get shelved. The ARC-Institute for Pasture and Animal Production (API) provides information on veld and rangeland management (Fouche, 2010 private communication). The ARC-API provides information only to commercial farmers through e-mail, telephone and information days. For example advisories are generated only when problems are identified, as the farmers call with a concern or where farmers are experiencing poor animal performance. Dr. Herman Fouche evaluates the condition of the veld and ultimately comes with a recommendation (advisory) as the stipulated veld management system that goes directly to farmers.

Commercial farmers in the south-western Free State at large have been exposed to commercial agrometeorological services to agrometeorological advisories for decades, resulting in their success in producing good quality crops (Fouche, 2010 private communication). The resource poor farmers for decades and decades have relied on traditional climate prediction indicators. This chapter wants to explore constraints identified for agrometeorological information/products dissemination, to assess the currently available agrometeorological services, to give an overview of climate/weather information/products suppliers, their customers, the channels used for information/products dissemination and the stakeholder networks using these channels. It also focuses on problems resulting in ineffective information/products dissemination in order to identify more proper channels of information/products dissemination.

2.5.2 Status of agrometeorological information/advisories assessed in September 2007

As earlier stated, small scale and commercial farmers in the south-western Free State were invited to participate in study groups and workshops to evaluate the status of agrometeorological information/advisories within this region. The scale of farming operations is determined by the size of the farm, the level of technologies applied, farm turnover, people employed and employee levels of skill or qualifications.

The survey was conducted amongst three categories of farmers:(i) small scale farmers, (ii) commercial farmers and (iii) commercial farmers that did not operate as such during the period of this study. The category of "commercial but not operational" farmers are those farmers who were awarded land by the government under the Land Redistribution

Programme of South Africa. Table 2.3 shows that in September 2007, 27% of the small-scale farmers, 87% of the commercial farmers and 33% of not commercially operational farmers indicated that they did have access to weather forecasting and climate prediction and specifically the inter and intra seasonal predictions. This confirmed that the commercial farmers had an advantage. The small-scale farmers must be considered disadvantaged by not receiving the weather forecasts and climate predictions, because the developers and suppliers of such agrometeorological information/products consider them as most crucial for improving decision-making and food security (Oram, 1989; FAO, 2002).

Table 2.3. Evaluation of receipt of weather forecasts and climate predictions in south-western Free State by September 2007.

Farmers with access to weather and climate information/products	N=100	**Small-scale** (n = 26)	**Commercial** (n = 44)	**Commercial but not operational** (n = 30)
	Yes	27%	87%	33%
	No	73%	11%	67%
	Total %	100	98	100

2.5.3 Existing suppliers of agrometeorological information

Interviews were organized across the south-western Free State and held with the institutions that provide agrometeorological or climate related information/products. The key informants were identified and interviewed. From the Provincial Agricultural Disaster and Risk Management Division within FS-DAFF, Mr. J. Wessels was interviewed in 2008, and Mrs. K. Dihltage and Mr. M. Mkoaqo were interviewed in 2010. The Free State ADRM unit was only in its developmental phase, so there was not much advisory work for early warning systems taking place. They only produced an information bulletin which provided the rainfall conditions of the previous months.

Representatives from the South Africa Weather Service were interviewed on types of information/products they produce. The SAWS produces different types of weather/climate forecasts/predictions such as now-casting (0-6 hours), weekly and fourteen days forecasts, monthly, seasonal and six months predictions. SAWS provide warnings of floods, hailstorm, frosts, heat waves and lightning. These products are available from the SAWS website (SAWS, 2009) and telephonically on request. Daily weather bulletins are broadcasted on national TV and radio stations in all South African official languages. Monthly meetings with the Provincial Disaster Management Committees (PDMC) are held to ensure information dissemination and awareness. SAWS has in the past given training sessions and short courses aimed at study groups for commercial farmers and extension officers (Rossouw, 2007; Kentse, 2008; Ndarana, 2012 private communication).

The University of the Free State specializes in training undergraduate and post graduate students. The Soil, Crop and Climate Sciences department also provides short courses to extension agents every now and then, in the application of weather/climate information/products for agricultural decision making. Its Agrometeorology Division also facilitates on-farm trials by deploying students to work hand in hand with the farmers and evaluate the impact of utilizing agrometeorological information/products. But these are ad hoc educational exercises and case studies and may not be categorized as weather and climate information/products/services provision for a certain target group as such.

Santam Insurance specialized in assisting farmers commercially with crop insurance and advisories on weather predictions and preventative measures to take. In addition, other private consultants commercially provide different agrometeorological services such as irrigation scheduling, drought monitoring and forecasting, crop estimates, natural disaster warnings and assessments. These are services because they are discussed and handled with the clients and paid by these clients.

The ARC-ISCW Agro-climatology Division works together with the ADRM to interpret weather forecasts and climate predictions produced by the SAWS and other institutions. The interpretation of these forecasts is used as a guideline to develop sound and suitable agrometeorological advisories. These advisories are then shared at the NAC, as the umbrella of stakeholders involved in weather/climate information/products formulation and dissemination. It is a committee whereby different stakeholders present their findings and experiences and thereafter develop a quarterly provincial report. These stakeholders are responsible for further dissemination of information/products to their members and ultimately to end-users.

2.5.4 Existing channels of information/products dissemination

Agrometeorological information as well as products/advisories and services can be made available to relevant end-users via different types of channels and in different formats. During interviews with the farmers, it became clear that knowledge and skill transfer through training to empower farmers is a necessity. Suppliers should use efficient methods of agrometeorological information/products/services provision as recommended by the farmers. Agrometeorological services providers have realized that there is a need for training and preparing end-users in/for the application and establishment of such services. We should remind ourselves that the resource poor and commercial farmers differ in their experiences, needs and challenges. Commercial farmers have access to electronic facilities such as e-mail, internet, telephones and fax, while most resource poor farmers rely on cell phones for which their use is not yet scientifically supported.

During the study it became clear that training of trainers should be the first priority. In the south-western Free State extension officers have very little experience or knowledge on the application of weather/climate information/products for decision making and this situation has worsened under the conditions of a changing climate. During the NAC meeting held in May 2010, a request was made to strengthen training for government officials so that they should be able to interpret seasonal predictions and provide advisories/services to their farmers. Such providers are still facing a huge challenge to get their products and services to all farming levels and water users, to ensure better water usage and other agricultural decision-making.

Information dissemination pathways utilized and established by DAFF-ADRM under the NAC are shown in Fig 2.6. As already stated above, the SAWS and ARC-ISCW are national monitors of automatic and mechanical weather station networks. As earlier explained the ARC-ISCW utilizes the climate data from the databank and seasonal predictions produced by SAWS to develop advisories, for example Umlindi, and daily disease reports (www.agis.agric.za). The Santam Insurance Company in the central Free State and parts of the Northern Cape Province receive the climate data from ARC and SAWS to produce downscaled seasonal predictions for commercial farmers and other private organizations. The advisories from the ARC, the weather/climate forecasts from SAWS and the predictions from ARC are then sent to their clients at a cost, and one of the clients is the DAFF-ADRM directorate. Subsequently, the provincial representatives within NAC are supposed to distribute the agrometeorological advisories to their provincial districts and eventually to the end-user. However, the reality is that in the south-western Free State, or the Free State at large, the information/products/advisories do not reach all types of end user, and services (in contact with farmers) are non-existent.

This study has brought out several negative points concerned with the dissemination of agrometeorology information/advisories/services in the south-western Free State. In summary, adding some new points also, during the baseline survey at the beginning of the study in 2007, the first outcome was (see above) that basically only commercial farmers receive advisories, as they have access to electronic media; the resource poor farmers rely on traditional climate prediction indicators. Secondly, a questionnaire given to 30 extension officers and other government officials in the workshop held in October 2010, showed that only 13% confirmed to have a good understanding and background of weather forecasting and climate prediction information for agriculture and 87% expressed to have very little or no knowledge in this regard. Thirdly, as already indicated, the ADRM unit in the Free State was only becoming operational in 2010 and has not been providing the farmers with any early warning information but it has only concentrated on post-disaster management. Fourthly, there is no system in place that allows the farmers or other end-users to provide feedback regarding the status of use and usefulness of the agrometeorological advisories and bulletins given to them. Fifthly, there is no existing linkage between the ADRM Free State and the MLM disaster committee, although they were given the same mandate under the Act 57 of 2002 on Risk and Disaster Management. However, the ARC and the University of the Free State have a direct link with certain target groups at grassroots level, but only for research and research educational purposes.

For any progress related to non-commercial emerging farmers, the agrometeorological information/products should be disseminated by trained people through established and verified channels of information/products dissemination and according to the preference of the farmers. It is certain that producers of agrometeorological information and advisories are well established in the Free State and South Africa at large. Currently, however, the non-commercial farmers most in need of assistance largely do not and cannot receive them in any well-organized way. The well-outlined illustration that presents the current situation in the Modder/Riet catchment (Fig. 2.6) shows linkages among the role-players within this system. The seasonal forecasters are at the top of the illustration, with the monitoring of databanks, and then follow the advisory producers for the disseminators of information/products that should ensure that this gets to and is utilized by end-users. The situation of that (non-) use was sketched above. Unfortunately, the system in place does also not allow for the feedback from the too few users to evaluate and improve the products.

A pathway that has been used with success in the south-western Free State is where strong links developed between ARC/Universities and the farmers. The gaps identified within the system were a lack of staff, while the existing staff was not well qualified and insufficiently skilled to be able to transfer agrometeorological information/products as new knowledge; other flaws were lack of effective communication, dissemination methods that did not exist or were not tested or evaluated, information provided or used in bulletins and advisories that was too scientific and could not be understood by most farmers even if they were sufficiently literate (see also e.g. Stigter, 2010).

In this 2007 baseline study some farmers found it difficult to make use of what reached them, the researchers and the extension officers operated in isolation and there was little sharing of information; in some districts there was a total lack of support from the extension officers to the farmers. Although there are strong linkages amongst stakeholders within the NAC, more emphasis on developing locally sound and tailor made advisories and identifying proper channels of information/product dissemination to most non-commercial farmers was still a big challenge in the south-western Free State in 2007.

The existing challenge for information dissemination is due to less skilled staff being involved that has no training in encouraging two-way communication. This situation therefore only encourages a top-down approach, if any efforts to reach non-commercial target groups are made at all. The information/products initiators do not understand the end-users perceptions about their products and so actually discourages effective communication. However, as confirmed by this study, participatory interaction with the farmers using focus groups, buzz questions, word of mouth, study groups and workshops allow two-way participation (Smith, 2006). This helps to understand the user's perception of the advisories, it allows a platform for constructive criticism that should lead to improvement of products and introduction of actual services, which are user friendly and translated into vernacular languages. Well trained intermediaries are essential to carry this mandate for the improvement of management practices across the farming community (Stigter, 2005). The institutions and networks for development and dissemination of information/products need to improve their services, with the aim of making sure that these services get to the users and they must provide channels for feedback (Mukhala, 2000). It is still highly necessary to improve the dissemination networks and establish feedback opportunities to facilitate the two-way communication amongst disseminators and farmers and other end-users (Ziervogel, 2004).

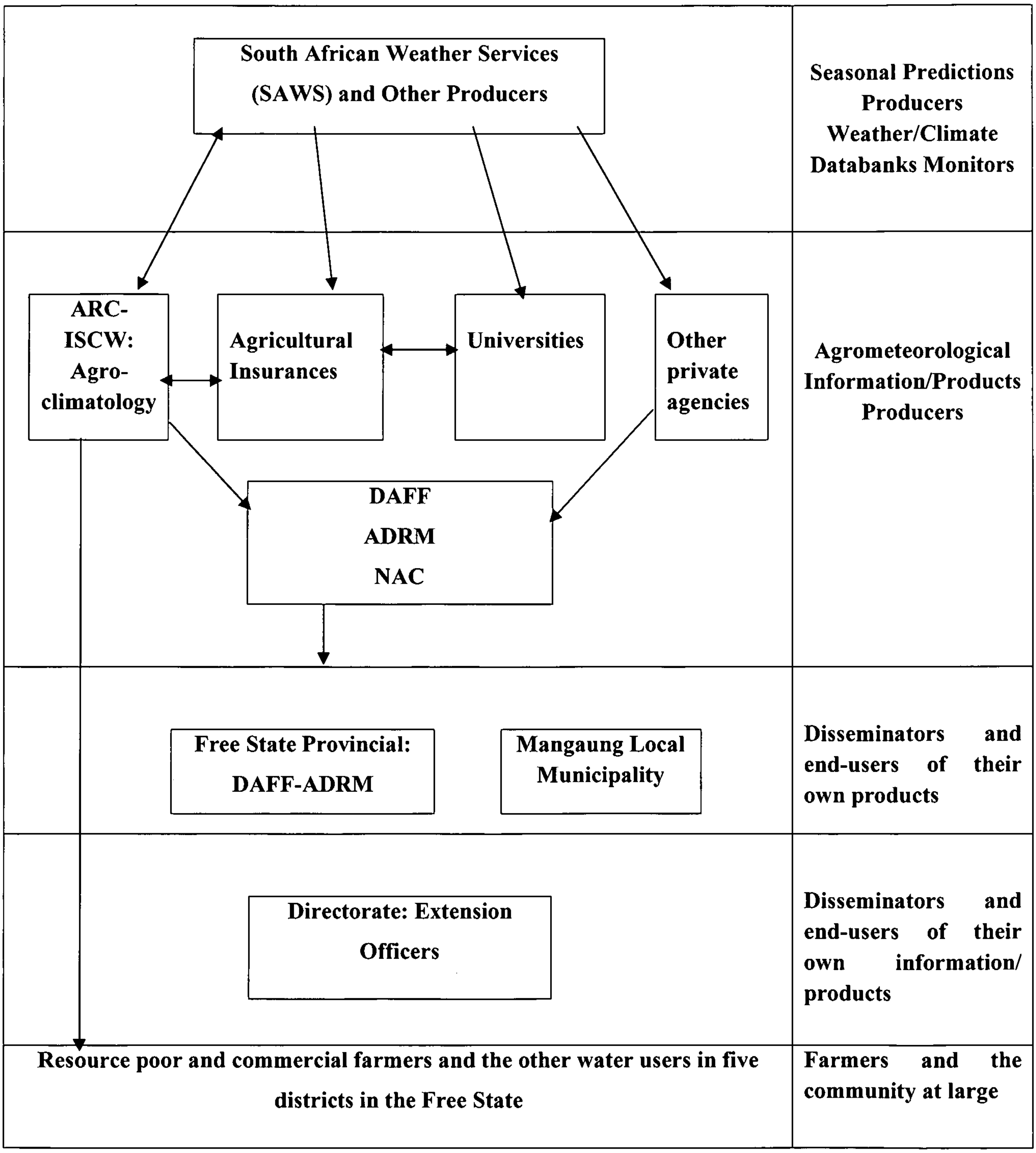

Fig. 2.6. Agrometeorological information dissemination pathways for south-western Free State.

2.5.5 The importance of using agrometeorological information/products

The participants in the 2007 survey were asked to express their opinions on the importance of considering weather forecasting and climate prediction products for deciding on which agricultural activities to undertake and their planning. The possible answers were sub-divided into four different categories, e.g. very important, important, unsure and not important. The outcomes showed that 53% of the farmers interviewed considered the forecasts/predictions very important for tactical and strategical planning, whereas 20% said that the forecasts/predictions were important for decisions on management activities (of course if they were provided in time). However, 25% indicated a degree of uncertainty as to the value of considering the forecasts/seasonal predictions when undertaking the agricultural activities and only some 2% indicated that they were not important at all (Fig. 2.7).

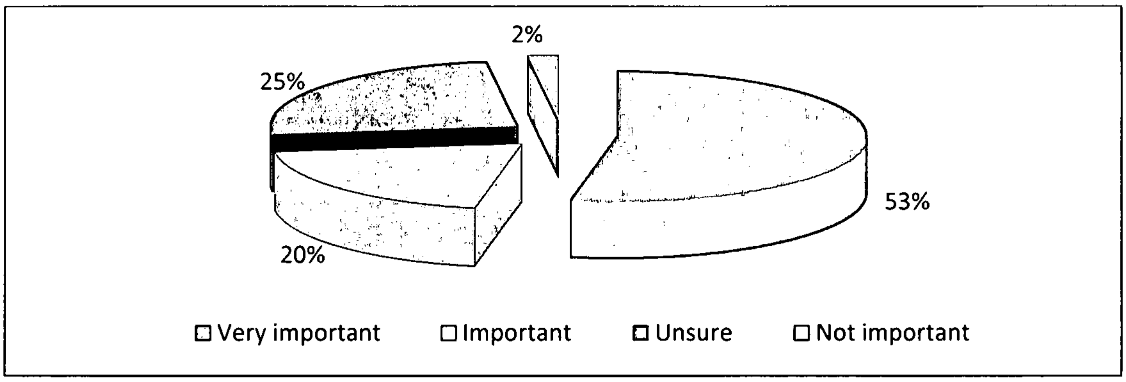

Fig. 2.7. Farmers opinion of importance of weather forecasts/climate predictions in agricultural decision-making (as in 2007).

The group that considered seasonal predictions as very important consisted mostly of commercial farmers with thirty to forty years of experience and own farms which were larger than 200 ha. Farmers at commercial level and with larger farms have utilized such agrometeorological products to guide on-farm decisions to make (Mukhala, 2000). This survey confirms with new data that larger farm owners indeed use these agrometeorological products.

For weather/climate products provided as a short-term forecast or long-term prediction, it is very important that they contain sufficient skill, so are reliable, well explained and applicable. The farmers responded as follows, when asked to share experiences on the reliability and trustworthiness of the seasonal predictions. Although they were considered very important, unreliability of the seasonal predictions remained a concern to some farmers. As much as

46% of the farmers indicated that they indeed were reliable at most times (Fig. 2.8). Another 20% considered seasonal predictions at least applicable and reliable at times. Also 20% thought that it is not at all reliable while 14% clearly mentioned that they were not sure, since they were not regularly exposed to weather forecasting and climate prediction for agriculture.

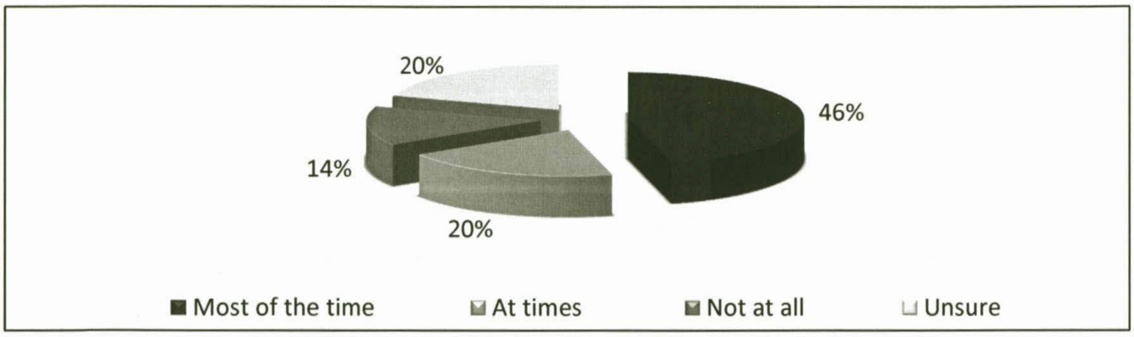

Fig. 2.8 Reliability of weather forecasts/climate predictions as assessed by the farmers

A further question was asked on whether farmers take initiatives or make efforts to request and obtain weather/climate agrometeorological /products/services, because should they be found useful, users should make an effort to acquire them. The outcome from the questionnaire analysis pointed out that 48% of the farmers would make efforts to obtain weather/climate agrometeorological /products most of the time, 17% will do so at times. However, 35% of farmers still consider such agrometeorological invalid for their purposes as they make no effort to obtain it (Fig. 2.9). Although there is a high percentage of farmers who do make an effort to obtain seasonal predictions, there is still much needed from the research side to train farmers on the interpretation of scientific agrometeorological/products and their application to farming activities (O'Brien, et al., 2000).

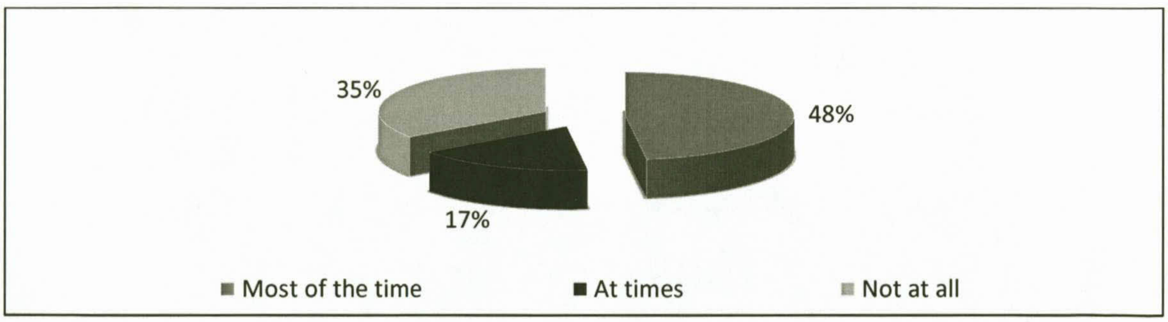

Fig. 2.9. Do farmers make efforts to obtain weather/climate and agrometeorological advisories (Appendix 1.7)?

A major problem raised by the farmers when requested to interpret the seasonal predictions at workshops was that it is too scientific, not point specific as it is difficult to find Bloemfontein on the given map, and the probabilistic nature of presentations is not well understood. Therefore, it shows that the seasonal predictions are presented in a highly scientific manner, which might be difficult to understand by the farmers and the extension officers. If these predictions were developed for the use of the farmers to improve their farming practices, it should be tailor-made for them. The agricultural scientists should use the weather forecasts and climate prediction and is this meant more generally as information/products/advisories designed by the climate scientists for generation of additional more relevant information products that pertain to the actual farming activities as also proposed by other authors (Gommes, 1998; Stigter, et al., 2000, Sivakumar, 2006; WMO, 2004;). Sivakumar (2006) stated that in Africa 80% of information providers have not made any effort to obtain feedback from users. This all showed that it was vital to spend much more time with the farmers, particularly by visiting their fields, so as to learn about the weather sensitive decisions that they must make, and to encourage feedback from the farmers. It is also vital to understand the needs of different users in sensitive decision-making, their actual use of information/products and their level of education, because farmers are diverse (e.g. Phillips et al., 2000).

For example, the farmers in the south-western Free State were requested to interpret the seasonal outlook and mention how they would use such information as presented by the SAWS (Figs. 2.10 & 2.11). There were different but interesting interpretations from the groups. This exercise showed that training of farmers to interpret and use such information/products is necessary and that other applications should be developed so as to utilize them.

The predictions of 9 November 2009 read that "Enhanced probabilities for below-normal rainfall totals are forecasted for the eastern parts of South Africa and most of Namibia" (Fig. 2.10). Zooming in to the south-western Free State, it indicates that during the period 18 November to 7 December 2009 there was a 60-70% chance of receiving below normal rainfall. It was well explained in the later study groups that this period was therefore not the best time for planting since the chance of receiving rainfall was expected to be very low and so the soil would be very dry. The farmers were also advised to wait until the onset of the first rainfall, at least 25 mm, and then plant when there is sufficient soil water in the soil. The condition that was predicted did actually occur, thus farmers developed confidence that the information can be reliable and applicable. Farmers who used this advice benefited as they waited for the best time to plant by adjusting their planning for the related farming operations. However, such a case study is not a real proof. This should be more systematically studied with well-defined groups of farmers.

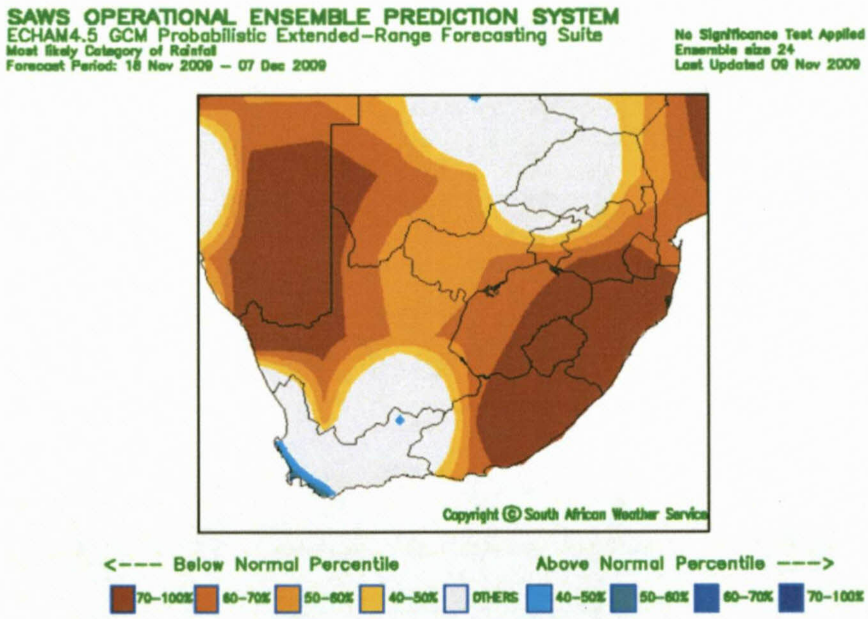

Fig. 2.10. The extended range rainfall for 18 November-07 December 2009 growing season issued on 09 November 2009.

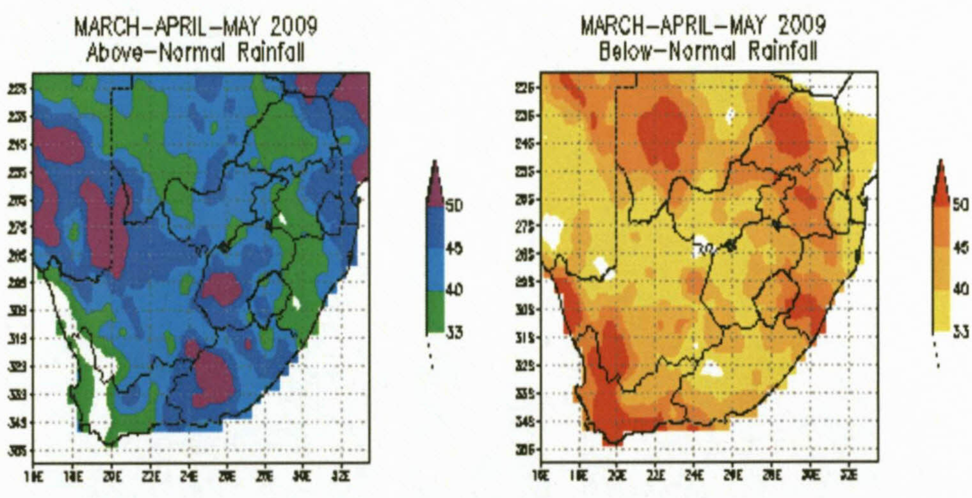

Fig. 2.11. Seasonal prediction for March to May 2009 harvesting season issued by SAWS on 28 January 2009.

Another example, in January 2009 the SAWS outlook indicated that "In March-April-May 2009, above-normal rainfall totals are expected over parts of the Free State, Eastern and Northern Cape, the Lowveld and northern KwaZulu-Natal. Below-normal totals are expected over the south-western areas and the larger parts of KwaZulu-Natal, Mpumalanga and the Limpopo Province." Zooming in to the south-western Free State Fig. 2.11 indicates that there was > 45% chance of receiving above-normal rainfall and about 33% chance of receiving below-normal rainfall. This information may be of some use to be able to adjust activities, such as cutting hay and harvesting maize and above normal rains were experienced.

However, it is easy to assume that the farmers understand terminology like normal, above-normal and below-normal but they mostly do not without discussions with scientists or well-trained extension intermediaries. If farmers cannot make sense of this terminology, that is a clear indication that the information on the seasonal prediction has not explicitly been communicated with enough explanations on the implications and so cannot be used for or integrated into the on-farm decision-making process. This situation must change. Also the implications of such a prediction might not really be clear even when they understand the terminology, so again this asks for interactions. Also, normal rainfall amounts from a 30 year cumulative distribution function of climatic data for the area can be shown. But doing so we have to realize that climate change may have distorted this distribution function, so we should also show one of the latest ten years. In Indonesia Stigter and Winarto (2012) use simple scenarios for the seasons derived from the climate predictions that express scientific outlooks.

Chapter 3

Supporting Farmers in Decision Making Using Science-based Weather Forecasts and Climate Predictions

3.1 Introduction

Application of weather forecasting and climate prediction research results in agricultural production has met with many limitations in general as well as related to the end-user in developing countries and most particularly related to resource poor farmers (Archer, 2003; Ziervogel & Downing, 2004). There has been rising interest in working with farmers in reaching out with new technologies and science-based information to many farmers (Erbaugh et al., 2007; Aw-Hassan, 2008). This comes together with a continuous requirement and need for abilities to translate technical detail into a digestible format. There is a gap between producers and suppliers from the national, provincial, regional and local networks and the users in need of weather forecasts and climate predictions for on-farm decision making. Another identified gap is how intermediaries ensure the encouragement for adaptation of agrometeorological information/advisories/services for decision-making (Mukhala et al., 2000). By identification of agrometeorological information/advisories/services producers and suppliers and stakeholder networks, intermediaries can become in the position to strengthen the channels of efficient agrometeorological information/advisories/services dissemination. Thereafter, identification of the constraints for effective adoption can be included to effectively encourage the adaptation of science-based information for use in improved agricultural production (Valente, 1995). Agrometeorological information/advisories/services use in on-farm decision making on a routine basis will improve productivity and minimize risks (Stigter, 2010).

Extreme meteorological events that are increasing in number and severity due to climate change are already serious enough. But they also have the potential to instigate and/or alter pest and disease infestations, which result in more crop damage and failure (e.g. Thornton and Cramer, 2012). Therefore, early warnings are crucial for preparedness so that interventions can be implemented to reduce possible damages and risks. The variability of weather within the season has significant impact on timing and planning of agricultural practices such as times of ploughing, planting, weeding and harvesting and of application of fertilizers and pesticides (e.g. Berggren, 1978; Thornton, 2012). The timely provision of agrometeorological information/advisories/services to farmers will assist strategic planning such as crop suitability selection and management practices for sustainable agricultural production (Weiss et al., 2000; Sivakumar, 2006; Stigter, 2010). Already a World Bank Report dated 1998/99 emphasized the importance of information and knowledge as 'factors of production,' as they play an imperative role in human development and behavioral change.

Accessibility and availability of agrometeorological services and information/advisories differ from country to country and for different types of farmers. For example resource poor farmers are disadvantaged since such information is not incorporated into their daily decision making (O'Brien et al., 2000). Agricultural information/advisories/services dissemination from developers to suppliers to farmers could reach a fair number of respondents in Malawi, Tanzania and Free State Province in South Africa (Mukhala, 2000) and in Lesotho (Ziervogel & Downing, 2004). Within the dissemination process several blockages and gaps can be identified such as lack of access to internet, difficulties in understanding technical terminology and information/advisories/services not reaching the end-users in time. Several constraints also occur in modelling the weather and climate systems as complexities exist within these systems, such that weather forecasts are not point specific, obtained at unsuitable temporal resolutions, with only few selected climate parameters predicted, and with the forecasts having little skill (e.g. Ziervogel & Downing, 2004). However, some agrometeorological advisories may still carry substantial support for practical decision-making, which can be disseminated through institutionalized study groups or any other well-established information dissemination channels and networks that allow the provision of feedback from end-users.

Meaningful and valuable advisories/services on weather forecasts and climate predictions for a wider agricultural community need to be well thought through and different types of network channels should be established. Science-based information should be made understandable through all channels of dissemination to all different end-users (Ziervogel and Downing, 2004). The nature of channels and networks through which the information/advisories/services should flow needs to be identified and reviewed in order to improve their transfer and applications. Day et al., (1995) explained that dissemination should be by means of two-way communication channels. These communication channels must advance the sharing of meaning and support abilities for successful application of information/advisories/services (Mukhala, 2000). According to Ziervogel and Downing (2004) in the case study they conducted it was imperative to determine effective methods and channels of information dissemination by achieving key points such as evaluation of the user's perceptions on weather forecasts and climate predictions, identification of suitable dissemination methods, establishment of the agricultural enterprises suitable per location, investigation of the interaction of users so as to uncover other existing networks and contextualizing the importance of weather forecasts and climate predictions within their wider decision making environment.

3.2 Farming units, challenges on-farm and science-based scenarios

3.2.1 Land ownership and land tenure

The South African Ministry of Agriculture and Land Affairs used a Land Redistribution for Agricultural Development (LRAD) approach to land reform which was implemented in 2001 (Ministry of Agriculture and Land Affairs, 2001). LRAD provided for an extended scale of grants, dependent on an increasing own equity contribution from emerging commercial farmers. The redistribution programme entailed three different components which are agricultural development, settlement and non-agricultural enterprises. The types of projects that are catered for included food security projects, equity schemes, production for markets and agriculture in communal land. The success of land redistribution is dependent on farmers having support services such as machinery to work the land, input supplies, research, extension, finance, markets, information and infrastructure (Lyne and Darroch, 2003). These support services may be provided by state ministries and private sectors. As earlier shown in this thesis, provision of agrometeorological information/advisories/services (see Chapter 1) could play a crucial function towards sustainability of crop productivity, animal husbandry and agroforestry. Numerous studies locally and internationally have shown that agricultural led growth has high potential to drive economic reform in developing countries through improved employment rates, on-farm and off-farm income generation etc. (e.g. IPA, 2012).

The eagerness to adopt agricultural technologies and science-based information/advisories/services depends upon the farmer's expectations for better and improved increments of outputs and reduction of constraints to his/her crop production. There are a number of constraints that hinder good agricultural production such as the lack of incentives to buy inputs, labour, land and others. Gender is yet another factor that affects production since females and males are allocated different tasks (Doss, 2001). A household represents a nuclear family consisting of husband (if not absent) as the head of the family, wife, and children and in other families the extended relatives such as grandparents, aunts, uncles and cousins are included. Of course there are many women headed households throughout sub-Saharan Africa. Doss (2001) defined household as a group of people living under one roof, eating out of the same pot and making some joint decisions. Farms in the south-western Free State are mostly owned by individual(s) (household(s)) or by a number of beneficiaries having shares on one farm. Therefore, to clearly understand the intra-household dynamics, it is crucial to know the livelihood of the farmers as the decision makers in its setup and the challenges faced by such farmers.

3.2.2 Collectivity in farming

Many households in the south-western Free State depend on farming and off-farm activities to generate income. Households who continue to practice farming have the responsibility of taking care of the fields, animals and agroforestry. There is a wide diversity of farming activities practiced across the selected area, which range from growing grains, vegetables, fruits, to keeping small and large stock animals. Mining salt pans is an important off-farm activity. My experience while engaging with the farmers was that farmers differ in land scale, skill, capacity and resources. There are farmers who own all types of implements to work the fields, with only few laborers needed, and there are farmers who depend on others to hire implements to work the land. Another group is formed by those famers who can even not afford to hire implements but own land that remains bare even during the cropping season. This depicts south-western Free State as a land of contrasts. There are those farmers who trade crop residues with animal producers as feed in exchange for land cultivation services, some with a prescribed amount of tons of maize traded for slaughtering chickens. Some farmers exchange laborers during transplanting, planting, weeding and harvesting. The culture of sharing and voluntarism among the farming community is encouraged in cases of farmers who are not able to perform certain activities.

Most commercial farmers, who are well provided with skills and equipment, do not require external assistance. Trading of commodities amongst all types of farmers is a common practice within south-western Free State. Exchange of information and skills occurs by few selected farmers through a mentorship programme designed by the Ministry of Agriculture, facilitated by extension agents. Dominant labour exchange is practiced among farmers to expedite agricultural activities. For example, during Swiss chard harvesting which is labour intensive, in Sannaspos Mr. Cangiso and Mr. Mokhethi exchanged labour. However, in case of farms that are owned by a number of beneficiaries from different households, farming activities are dispensed amongst beneficiaries. There are cases whereby hiring of casual labor is the only viable option for farmers who are engaged in other off-farm activities to generate extra income. Farming in the south-western Free State consequently requires individual household and collective group work to ensure timely execution of activities for sustainable agricultural production.

3.2.3 Farmer differentiation

A recent 2012 additional survey of farmers in the south-western part of the Free State, in two district municipalities of Motheo and Lejweleputswa, explored among others the farm systems, the application of weather forecasts and climate predictions and the accessibility and availability of other agrometeorological information/advisories/services. The south-western Free State is encompassed by the Modder/Riet catchment. The survey was conducted in the following towns as shown in Fig. 3.1: Sannaspos, Brandfort, Soutpan, Dewetsdorp, Bloemfontein, Thaba Nchu Botshabelo, Verkeerdevlei, Koffiefontein, Jagersfontein, Tromsburg and Ladybrand. The number of farmers interviewed per town, their group status, farming enterprises and land tenure status (owner, tenant, worker or other) are indicated in Table 3.1. During the survey, farmers from different levels were given a set of questionnaires designed to assess three major factors: (i) the farming systems, (ii) the availability of weather forecasts and climate predictions to the farmers and (iii) the use of such science-based products by the farmers.

In the study area, the annual rainfall differs significantly and ranges between 200 mm and 700 mm (Fig. 3.1). It should be noted that the catchment under study is divided into three in terms of annual rainfall categories. The annual rainfall on the western part of the catchment ranges from 200-300 mm, which is an indication of severely dry conditions, the middle part of the catchment ranges from 500-600 mm of annual rainfall and the eastern part of the catchment is a wetter area compared to the other parts, with 600-700 mm of annual rainfall. Therefore, the challenges faced by the farmers and farming systems also differ a lot. Amongst farmers interviewed, close to 53% were commercial farmers (CFs) and just over 47% were resource poor farmers (RPFs) (Table 3.1). These farmers were identified practicing grain, vegetable and fruit production under rain-fed and irrigated conditions. Animal husbandry and agroforestry are also substantial agricultural enterprises within the study area. Rain-fed and irrigated conditions are defined as part of farming systems that seek to maximize the management and the implementation of agricultural activities timely. The following crops were planted by the farmers during the period under consideration: grains (maize, wheat and sorghum), sunflowers, vegetables (potatoes, Swiss chard, beetroot, cabbage, carrots and peppers), fruits (apricots, peaches, pears, apples and plums). Livestock production is yet another active agricultural enterprise. For example, poultry (broilers, layers, geese, ducks and turkey), large stock (cattle, horses and donkies) and small stock (sheep, goats and rabbits) (Table3.1).

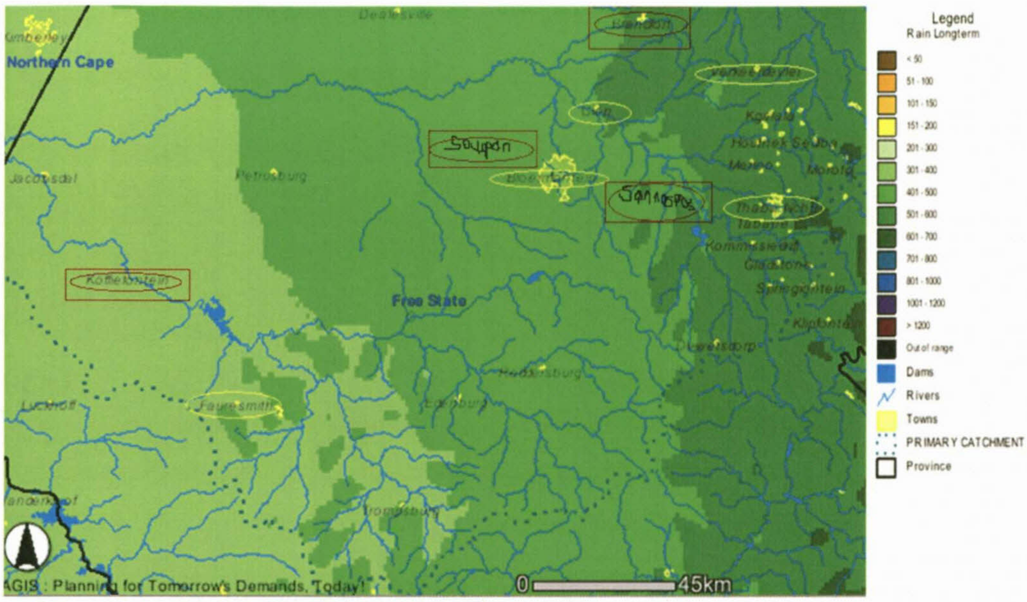

Fig. 3.1 Map showing the distribution of towns of the study area and the differences in annual rainfall (also Chapter 1).

During the survey it was discovered that farming systems, agricultural practices, farming interests and needs, agricultural skills and experience differed from farmer to farmer. According to the analysis, farmers were requested to list agricultural enterprises involved in and the response was as follows: crops 4%, livestock 25%, mixed farming (crops and livestock) 35% and agroforestry (crops and trees) 36%.

During the survey, informal and formal groups were identified with the assistance of the local or district extension agents. In other cases local development managers together with the local municipal councilors were identified as functional entrance point to access farmers for research purposes. Formal groups refer to an organized study group, which is registered as a co-operative, and informal groups refer to farmers who form part of a study group, yet not registered as group but on individual basis. The formally registered co-operatives which are operational were identified in the following towns Sannaspos, Botshabelo, Bloemfontein, Koffiefontein, Jagersfontein, Thromsburg and Ladybrand (Table 3.1).

Table 3.1 Study groups with consideration of farming systems, group status and land tenure status

Area	Number of farmers interviewed	Type of farmers	Group Status (Formal or Informal)	Farming Systems	Land tenure status (Owner, tenant, worker or other)
Sannaspos	30	CF=10 RPF=20	1 Formal group Informal groups	Livestock, fruit, grains, vegetables and production under rain-fed & irrigated conditions	40% owner, 10% tenant, 30% worker, 20% other
Brandfort	27	CF=19 RPF=8	Informal groups	Mainly livestock, grain production under rainfed conditions and vegetable production under irrigation	59% owner, 15% tenant, 26% worker
Soutpan	33	CF=10 RPF=23	Informal groups	, livestock, grain and vegetable production under rain-fed.	69% owner, 9.% tenant, 22% worker
Dewetsdorp	31	CF=8 RPF=23	Informal groups	Livestock and vegetable production under rainfed conditions	61% owner, 7% tenant, 32% worker,
Bloemfontein	45	CF=28 RPF=17	2 Formal groups Informal groups	Livestock, grain and vegetable production under rainfed & irrigated conditions	53% owner, 16% tenant, 24% worker, 7% other
Thaba Nchu	40	CF=31 RPF=9	Informal groups	Livestock, grain and vegetable production under rainfed & irrigated conditions	83% owner, 10% tenant, 7% worker
Botshabelo	15	CF=3 RPF=12	1 Formal group Informal groups	Livestock and vegetable production under rainfed and irrigated conditions	87% owner, 7% tenant, 7% worker
Verkeerdevlei	31	CF=10 RPF=21	Informal groups	Livestock and vegetable production under rainfed and irrigated conditions	88% owner, 13% tenant
Koffiefontein	25	CF=15 RPF=10	4 Formal groups Informal groups	Livestock and vegetable production under intensive irrigation conditions	76% owner, 12% tenant, 4% worker, 8% other
Jagersfontein	35	CF=10 RPF=25	1 Formal group Informal groups	Livestock and vegetable production under intensive irrigation conditions	77% owner, 17% worker, 6% other
Thromsburg	37	CF=12 RPF=25	2 Formal groups Informal groups	Livestock, fruit, grains, and vegetable production under rainfed & irrigated conditions	46% owner, 24% tenant, 22% worker, 8% other
Ladybrand	40	CF=36 RPF=4	4 Formal groups Informal groups	Livestock, grain and vegetable production under rainfed and irrigated conditions	53% owner, 25% tenant, 20% worker, 3% other

In the study the socio-economic analysis was conducted across the chosen districts of Motheo and Lejweleputswa. Following the study groups and workshops in early 2008, twelve distinct groups, with farmers ranging from 15 to 45 members were surveyed. The selected target areas have great similarities in rural population, grazing land area, cultivated land area, farming systems, challenges in accessing agrometeorological information, and educational level of farmers (Table 3.1; Table 3.2). Grain/oil crops such as maize, sunflower and wheat, vegetables such as Swiss chard and cabbage, small stock and large stock are the farmer's most important agricultural enterprises in the surveyed areas. Two groups of farmers were interviewed, in 2008 (394) and 2012 (130) respectively, the numbers partly overlapped and they consisted of randomly selected farmers who had access or no access to agrometeorological information. The workshops objectives were to facilitate consideration of guidelines and advantages of weather forecasts and climate predictions among farmers within the study area and to promote awareness of the application of other agrometeorological information/advisories/services for improved decision making. The contents of the workshops included education and training from intermediaries to farmers and farmers to farmers. There were several major subject areas: methods of information dissemination, interpretation and application of weather/climate information/advisories/services, traditional climate information and suppliers of information. The workshops were centered at learning and using "know how" on the application of agrometeorological information/advisories/services for better productivity.

Groups of farmers were selected to determine to what extent acquired knowledge on the application of agrometeorological information/advisories/services had been diffused from suppliers to users and from user to user or farmer to farmer. Inception workshops were conducted for brief explanations on the objectives of the research project and an oral consent to participate was given by the farmers. Farmers passionately participated in meetings to exchange information. The participants in our meetings were fulltime and part time farmers earning income with agricultural activities and off-farm activities. The mean age of farmers was very close to 57 and close to 47 years for 2012 and 2008 respectively (Table 3.2). It is also worthwhile mentioning that in 2012, 30% and in 2008, 42% of the farmers indicated that they had no access to seasonal forecasts, so 70% in 2012 and 48% in 2008 had access to seasonal forecasts. This shows the influence that the workshops had. Two types of farmers were characterized as commercial farmers, with the landholding of above 5ha and operating intensive agricultural activities. Resource poor farmers were those operational and non-operational farmers lacking resources to implement agricultural activities successfully.

Table 3.2 Socio-economic variables for interviews conducted in 2012 and 2008

Variable	Farmers interviewed 2012 (n=130)	Farmers interviewed 2008 (n=394)
Gender	15% female, 85% male	9% female, 91% male
Years (age)	56.98	46.63
Number of people/household	4.38	4.62
Full time farmer	18.46% no, 81.54% yes	23.35% no, 76.65% yes
Farm size (ha)	range from 1ha - 1800ha	range from 0.5ha – 2100ha
Crop Production (ha)	range from 1ha - 600ha	range from 0.5ha - 580ha
Grazing camps (ha)	range from 1.5ha - 700ha	range from 1ha - 1000ha
Trees (ha)	range from 0.5ha - 120ha	n/a
Turnover (ZAR)	range from R7000 - R 3000 000	range from R24000 – R1100 000
Receipt of seasonal predictions	30% no, 70% yes	42% no, 58% yes

Qualitative data was collected through face-to-face interviews with farmers with the use of participatory tools such as focus groups, informal and formal interviews using structured questionnaires, key informants, transect walks, farm visits for observations, buzz or probe questions and resource maps. The key informants were selected from organizations responsible for agrometeorological services, advisories and information which are developers and suppliers of information. The key informants were identified from the following list of institutions:

- ✓ South African Weather Service (SAWS),
- ✓ Agricultural Research Council Institute for Soil, Climate and Water (ARC-ISCW),
- ✓ Institute for Pasture and Veld Management(ARC-API),
- ✓ Free State Department of Agriculture, Forestry and Fisheries (FS-DAFF),
- ✓ University of the Free State(UFS),
- ✓ Santam agricultural Insurance company,
- ✓ National Department of Agriculture Forestry and Fisheries(DAFF),
- ✓ Mangaung Local Municipality (MLM), and Senwes.

These interviews took place at their farms, at workshops or at study groups. The questionnaires were based on researched scientific information topics including farmer experience on traditional forecasting. Precisely, farmers were requested to list their agricultural enterprises and to mention whether they received any type of advisories which were agrometeorology related, including methods of information dissemination as preferred by the farmers. Space to list traditional indicators for weather/climate forecasting was also provided. Besides closed questions, sufficient free space for any other comments (should it be necessary) or alternative answers were included. Additional information on farmers to analyze socio-economic status related to age, gender, number of household members, education, land tenure, hectares of cultivated land, hectares of grazing land, hectares of trees, farm turnover (Table 3.2), availability and reliability of weather forecasts and climate predictions was also incorporated into the questionnaires.

One other factor which is worth mentioning is the preferred methods of information dissemination as chosen by the famers. The preferred media of receipt was rated as follows: close to 4% preferred radio, 3% preferred television, 27% preferred active internet, just over 28% preferred meetings or study groups, almost 5% preferred e-mail (passive internet), 11% remained unspecified and 22% indicated none. During interaction with the farmers good rapport was built. The inception workshops were held across the study area to explain the objectives of the project. The aims of the project were articulately presented through a power point presentation and distribution of pamphlets. Understanding and speaking the local people's language is the most important factor to be easily accepted in the community. The importance of the project and its content was fully explained to famers.

During workshops, interesting discussions came up amongst farmers as they were asked to name the most preferred method to disseminate weather forecasting and climate predictions and other agrometeorology related information. The aim of this exercise was to list advantages and disadvantages for each mode of communication selected (Table 3.3). The methods of dissemination were thoroughly discussed to explain the advantages and disadvantages for each method of dissemination as suggested and preferred by farmers. The most popular method was the monthly meetings, since farmers are able to react and ask questions to intermediaries, followed by radio broadcasting, local freely available newspapers and lastly via the extension officers in places where extension support was recognized. Famers expressed crucial needs for tailor-made advisories for improved in-season decision-making for reduction of risks.

Table 3.3 Advantages and disadvantages of method of dissemination as listed by the farmers

Dissemination Methods	Advantages	Disadvantages
E-mail	• Fairly convenient, can give all types of information for transfer	• Only few selected farmers have access to internet
Radio broadcasting	• Farmers can get information in local language and on time	• Might be broadcasted while famers are engaged in field work
Newspapers	• Good and suitable information can be accessible	• Not easily accessible on farms and it is costly to travel
Monthly meetings with study groups	• Good platform for farmers to be trained and can ask question as per individual concerns • Good opportunity for farmer to researcher interaction	• Project has a specified lifespan and thereafter the farmers will not continue to have access to weather/climate information
Extension Officers	• Advisories sent to Director of Extension, Extension Officers as well as to famers • Farmers should be able to ask EOs for clarity where necessary	• Some extension officers are not consistent with their farm visits • Some EOs are not well trained to be able to explain agrometeorological advisories

3.2.4 Stakeholder Interaction

According to Olande and Landin (2005) many different interests must be taken into consideration. Stakeholders are the representatives of their interests in a project. A project stakeholder is a person or group of people who have a vested interest in the success of a project and the environment within which the project operates. (Gibson, 2000). Seemingly, there is also a high demand from the farming community and research councils to close the existing gap between the developers of information/advisories/services and their users and to initiate new networking to share knowledge and improve channels of communication (Watson, et al., 2002). During the study period stakeholders involved, particularly as agrometeorological producers and suppliers of knowledge were invited to take part in interviews.

A Venn diagram represents a diagrammatical illustration demonstrating the relationships amongst farmers and other stakeholders see further below. The stakeholder analysis was conducted using the matrix (Anteneh, et al., 2004, Mataxes, et al., 2005) and the Venn diagram (Farnwoth, 1998, Anteneh, et al., 2004, Mataxes, et al., 2005) to identify and classify institutions and organizations that are capable to render and are responsible for weather/climate related assistance into the farming community within the objectives of this study. Through stakeholder analysis the farmers identified potential stakeholders by brainstorming whereby the names of all stakeholders were listed and ranked for their importance and influence (Fig. 3.4).

The primary and secondary stakeholders that participated during stakeholder analysis processes were identified and divided into typologies as the information developers or suppliers (Dunnell, 1986). During stakeholder analysis, the focus group participatory tool was used to facilitate the listing and the grouping of stakeholders, whereby the farmers were sub-divided into smaller groups to improve interaction, reflection and analysis. The analysis indicated that farm owners were ranked high as key people to ensure that suitable management practices are adopted to improve crop production for better financial status, should they be provided by the agrometeorological advisories timely and accurately (Table 3.4). This matrix illustrates the interests, potential impacts and the relative priority of interests. A higher positive status means that a particular stakeholder is more important, more influential and possesses a potentially higher impact in this study. The Water Research Commission, Agricultural Research Council (ARC) and University of the Free State (UFS) were ranked with high priority of interests as they are supposed to provide funds and opportunities for research to improve farm conditions (Table 3.4).

Furthermore, farmers used a Venn diagram (Fig. 3.2) to illustrate the influence and support of stakeholders to their daily decision making for agricultural purposes. Secondary stakeholders placed closer to the primary stakeholder are an indication of higher influence and support for farmers. Those placed far from primary stakeholders possess a lower degree of influence and support. The farmers indicated that they are more supported by the DAFF and Grain SA than by other organizations such as ARC, Agricultural Unions and the Water Research Commission. This illustration contradicts the output from discussions with the farmers as farmers felt rather neglected by the Provincial DAFF. Monthly visits to interact with the farmers played a good role for learning farming systems and exchanging information as the research project of this study progressed.

The stakeholder matrix (Table 3.4) and Venn diagram (Fig. 3.2) were the result of a fairly simple stakeholder analysis exercise that allowed farmers to understand what may be expected from different organizations that have different purposes and intentions. During the development of the stakeholder list, it was very important for the famers to be allowed to voice their challenges and identify the stakeholder(s) that can bring sound solutions on the matter. The Venn diagram showed that the Department of Agriculture was ranked as most highly influential, supportive in providing farms bought by the Department of Land Affairs, regardless of complaints and concerns about lack of support from extension officers. Grain SA was regarded as very supportive in training farmers on farm management, maize production and tractor maintenance across the study area. Other stakeholders with low influence lie at a noticeable distance, although the farmers in fact required more support at grassroots levels. During workshops with the primary stakeholders (i.e. farmers, extension officers and researcher), there was no stakeholder mentioned for the list that provided services on weather forecasting and climate predictions in 2008.

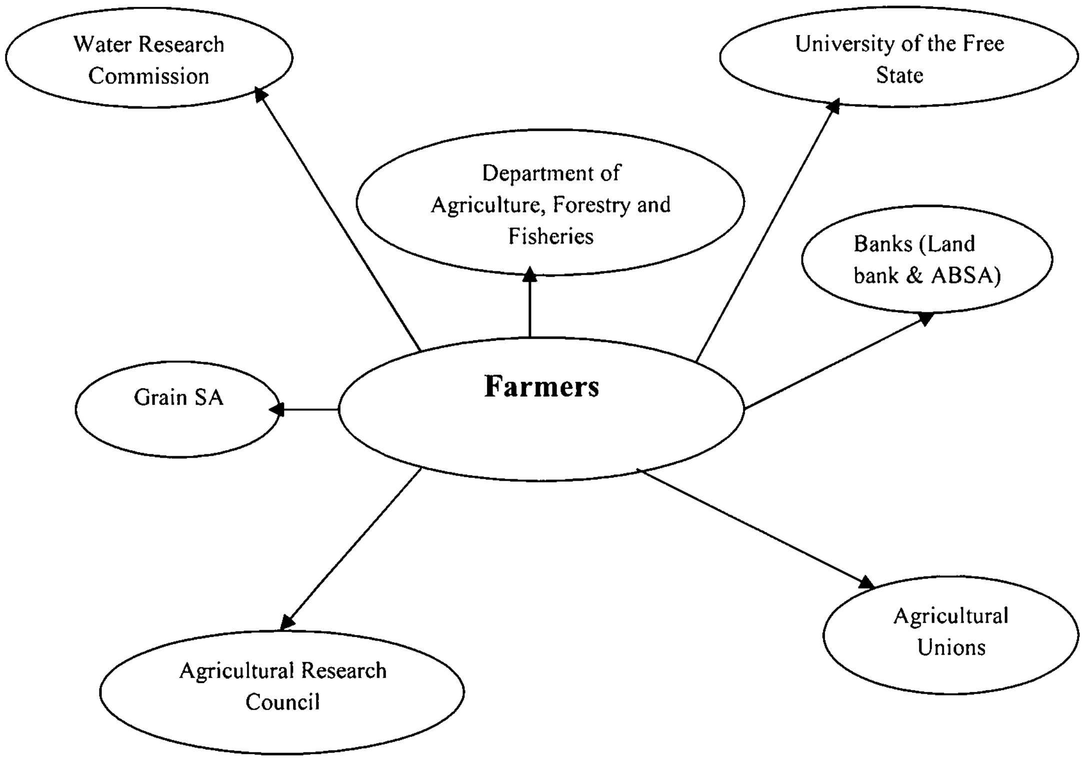

Fig. 3.2. Farmer's perceptions on secondary stakeholder influence and support using a Venn diagram.

Furthermore, this was an indication that farmers had no access to agrometeorological information/advisories/services in the south-western Free State. The stakeholder analysis process helped the team to understand the interests, potential impacts, influences and the importance of involved stakeholders and their role with the farmers. This process gave a clarification on the role of each stakeholder, to avoid unnecessary conflicts and confusion. It is very important to identify both primary and secondary stakeholders, as represented in Table 3.4, at an early stage of the study, and also to understand their impacts in the study

(Doherty and Hope, 2000, Brinkerhoff, 1998). Therefore, stakeholder analysis became a primary part of the study management as it clarified at an early phase of the study the interests, roles and contributions of different stakeholders. This process is very crucial to assist farmers to identify key stakeholders that can provide various services.

Table 3.4 Stakeholder matrix as identified by farmers for south-western Free State in 2008

	Interests	**Potential Study Impact**	**Relative priorities of interest**
	Primary Stakeholders		
Farm owners	Would like to produce good quality crops and be able to utilize agrometeorological advisories/services to their advantage. They also need financial support for purchase of inputs.	++	High
Farm workers	Would like to be well trained in application of rainfall forecasts and predictions to advance crop production.	+	Medium
	Secondary Stakeholders		
Water Research Commission	Provides funding	+++	High
Agricultural Research Council	Provides technical and science-based agrometeorological advisories	++	High
Dept of Agriculture	Provides land and extension services and sometimes inputs and implements	++	Medium
Grain SA	Training on farm management	++	Medium
Land Bank	Provides loans	+	Low
ABSA Bank	Provides loans & financial management	+	Low
University of the Free State	Technical support, formal and informal training, but not formally to farmers	++	High
Agricultural Unions	Provides funding and mentoring	_	Low

3.2.5 Challenges faced by farmers across Modder/Riet catchment

Farmers across the catchment are faced by different challenges and drawbacks to sustainable agricultural productivity. Regardless of the type of agricultural enterprises practiced by the farmer, one or the other way there will be limitations. But by a properly integrated approach famers may reach optimal production. Therefore, during interactions with the farmers, needs analysis exercises were conducted using the structured interviews method which is an approach to ensure that the each interview is presented with exactly the same questions in the same order (Kvale and Brinkman, 2008). Farmers from different agricultural practices and levels were interviewed. These interviews occurred in 2012. Interviews and other participatory tools were used to exchange information with farmers to share challenges experienced at grassroots level (Appendix1.11). Commercial and resource poor farmers participated. They listed and prioritized challenges on-farm and those that are weather/climate related.

As listed by farmers from different towns across the area, Table 3.5 is a list of challenges faced by the farmers regardless of the farmer status or the land size as owned by farmers. This gave indications that, like for most farmers in developing countries, agrometeorological information/advisories/services are not accessible to the farmers although many problems are weather/climate related. Amongst other challenges listed by the farmers, rainfall scarcity and the haphazard distribution of rains within the season were considered the most threatening of all, followed by severe frost conditions in winter as well as the outbreak of pests and diseases in animals and crops. Lack of access to agrometeorological information/advisories/services related to drought, hailstorms, lightning, wilting of plants, unpredictable onset of rains, drying of soils were other factors mentioned by farmers that contribute to poor productivity.

Given this situation, it is understandable that decision support tools used in developing countries were developed somewhere else. Weather stations are mostly not specific for rural areas since they are not on-farm but mostly in or near bigger towns and that may affect the development of tailor-made advisories, particularly where local conditions determine what will happen to crops like in pests and diseases and rainfall distributions. Therefore, new technologies and most importantly agrometeorological information/advisories/services are needed to significantly train farmers and to increase and improve agricultural production. Such technologies are based on the choices/selection of agricultural enterprises, planting choices, dates and densities, applications of fertilizers (kinds, amounts and dates) and pesticides, weeding times and frequencies, and irrigation scheduling. Therefore, also provision of daily to seasonal scenarios for decision making, based on weather forecasts and climate predictions, is crucial to influence the application or implementation of agricultural activities. Farmers need to be supported with such advisories prior to the planting seasons, within seasons and off-season for better preparations. Provision of inter- and intra-seasonal weather/climate outlooks is necessary, wherever possible to a reasonable accuracy, to minimize risks.

Table 3.5 List of predominant limitations (in order of importance given to them) which are weather/climate related as experienced by farmers in different localities

Sannaspos	Brandfort	Soutpan	Koffiefontein
1. Rainfall variability 2. Lack of rains 3. Severe frost 4. Wind storms 5. Droughts 6. Black frost 7. Outbreak of diseases 8. Lightning	1. Lack of water 2. Rainfall variability 3. Frost 4. Outbreak of diseases 5. Outbreak of pests 6. Lack of skill to use weather/climate information	1. Scarce rains 2. Severe frosts 3. Hailstorms 4. Rainfall variability 5. Long dry spells 6. Drying out of boreholes 7. No weather stations	1. Scarcity of rains 2. Long dry spells 3. Hailstorms 4. Droughts 5. Drying of streams 6. Low temperatures in winter
Dewetsdorp	**Bloemfontein**	**Thaba Nchu**	**Botshabelo**
1. Scarcity of rains 2. Long dry spells 3. Strong winds 4. Outbreak of crop diseases 5. Wind storms 6. Droughts	1. Rainfall variability 2. Severe frosts 3. Long dry spells 4. Hailstorms 5. Late or too early rains 6. Wilting of crops 7. Outbreak of locusts 8. Outbreak of other pests 9. Outbreak of diseases 10. Manifestation of weeds	1. Scarcity of rains 2. Long dry spells 3. Severe frosts 4. Hailstorms 5. Dry soils 6. Lack of irrigation water 7. Water logging	1. Scarcity of rains 2. Manifestation of weeds 3. Hailstorms 4. Long dry spells 5. Soil erosion 6. Wilting of crops 7. Discoloration of plants
Verkeerdevlei	**Jaggersfontein**	**Thromsburg**	**Ladybrand**
1. Long dry spells 2. Scarcity of rains 3. Manifestation of weeds 4. Outbreak of diseases 5. Drying of crops prior to maturity 6. Outbreak of diseases	1. Rainfall variability 2. Severe frosts 3. Black frost 4. Droughts 5. Weeds 6. Diseases 7. Dry spells	1. Lack of water 2. Rainfall variability 3. Frost 4. Outbreak of mosquitoes 5. Outbreak of insect pests 6. Dry spells	1. Rainfall variability 2. Manifestation of weeds 3. Outbreak of diseases 4. Droughts 5. Hailstorms 6. No suppliers of forecasts 7. Non-existence of simple probabilistic forecasts of rains

On the use of science based weather/climate information and advisories such as weather forecasts, early warnings of droughts, frost and hail, 17% had no idea of such advisories, 37.5% thought that they were very important and useful for agricultural decision making, 3% thought that they were useful to a certain extent and a bit more than 42% thought they were valuable. On traditional knowledge about 62% of famers confirmed its use and almost 38% mentioned that they did not use it on-farm, with 56% who mentioned that it was trustworthy and almost 44% who indicated that it was not trustworthy. Of these same farmers more than 54% indicated that traditional climate predictions were reliable and just over 45% indicated that they were not reliable and they were just a myth. On the reliability of science-based weather/climate information/advisories the results were as follows: not sure 31.5%, reliable 61.5% and not reliable 7%. Only 47% of famers thought of traditional knowledge based weather/climate information as reliable and 53% thought it was unreliable. Interestingly, most farmers (at just over 75%) were able to interpret normal, below normal & above normal climate conditions and only just below 25% could not provide interpretations of such climatic conditions. As to the interpretation of the use of probabilities of 30%, 60% and 90 % most farmers (96%) were able to interpret them, almost 58% of farmers had experience with using seasonal climate predictions and science based weather/climate information/advisories in planning and at least 94% of farmers were able to make adjustments upon drought predictions.

Only 50% of farmers made efforts and 50% did not make efforts to obtain climate predictions and other science based weather/climate information/advisories in comparison with only 47% making efforts and 53% not making efforts to obtain traditional climate prediction and other traditional weather/climate information. Supplies of traditional weather/climate information were found highest to take place from farmer to farmer (at 44.5%). Farmers who relied on their own experience rated 5.5% and 50% had no idea where to obtain such information. Most farmers were not satisfied with the quality of extension services regarding agrometeorological information/advisories. Amongst these farmers it was indicated that they only met with extension officers once a month (21.5%), on quarterly basis (11.5%), once in a while (26.5%), when there was a need (14.5%), and never (26%). This remains a huge challenge in the south-western Free State since extension agents are key people for farmers and are assumed to be the agents to disseminate and explain the use of weather forecasts and climate predictions and other weather/climate information/advisories/services for agricultural strategic and tactical operational planning for improved productivity. Therefore a strategy needs to be developed to beef up such extension services in the south-western Free State.

Rainfall scarcity remains a major limiting factor, not only in the study area but across southern Africa. Water unavailability for supplementary irrigation and rainfall anomalies restrict productivity of quality crops and the implementation of proper farming activities. Therefore, provisions of weather forecasts and climate predictions through extension agents or other intermediaries could certainly assist farmers to better know what activities to engage in and when, to reduce risks. Weather forecasts and climate predictions should be as accurate and timely as possible with the inherent skills and the lack of skills depending on actual climate and time of the year, for effective planning. Early and late unexpected occurrences of severe frosts often cause remarkable damages to crops, most especially during sensitive stages during germination, flowering and milking. From an agrometeorological perspective, it is therefore essential to assist with the provision of weather forecasts and climate predictions, including such frost forecasts. Should farmers be given the privilege of utilizing agrometeorological information/advisories/services timely during planning, this might substantially lower taking wrong decisions that lead to lower yields or even crop failure.

A range of trustable weather forecasts can be obtained from 0-6 hours, daily, for some more days and ultimately weekly. Relevant local agroclimatological parameters together with agronomic factors may assist in the development of tailor-made advisories that address the improvement of strategies to cope with harsh climatic conditions such as droughts. For example during drought seasons farmers are advised to be careful with their crop choice because in such conditions drought tolerant crops are advisable (for example sorghum instead of maize), or to decrease plant population, or to sell some livestock, or to apply mulch to preserve soil water content. Agricultural drought and all other types of droughts pose a huge threat to crop and animal production (USGCRP, 2009; Bannayan et al., 2010).

Supplementary irrigation is in fact necessary during prolonged dry spells and during droughts to enhance farming activities. Farmers who are located along Modder or Riet River are fortunate to be able to consider irrigation scheduling and to implement agricultural activities even prior to the first rains. Therefore, these farmers are not limited by the rainfall conditions for the season but use (supplementary) irrigation for their advantage for better productivity as long as they are allowed to take their shares. Farmers were well taught during meetings on how to augment seasonally available rains by using supplementary irrigation and to avoid water wastages. In this case farmers may be advised to irrigate given amounts of water calculated from local crop water requirements (Allen et al., 1998) and not to irrigate during rainy days. It is also very important to irrigate during cool hours of the day to minimize loss of water through evaporation from the soil or wet leaves. Increasing plant density is advisable since supplementary water is administered to the crops. As for livestock, there should be sufficient drinking points and trees for shade, during hot and dry seasons, to avoid dehydration and heat stress.

Prior to the inception of this study farmers relied on the daily forecasts as presented on South African Broadcasting Company (SABC) network to view and be updated on weather conditions. The daily broadcasts from SABC television and radio seemed to be the only sources that supplied weather forecasts that could also be used by farmers. Therefore, as we have stated earlier, the use of traditional seasonal forecasts is yet another area which requires thorough research and documentation on how it can be incorporated with scientific information.

Yet another concern is that about 60% of farmers in the study area lacked basic farm management skills. For example in Sannaspos lack of extension support was the main concern and this frustrated famers. The study group members battled on to whom to raise questions about their challenges. Farmers were faced by a number of challenges such as for example poor agricultural levels on-farm and poor support from the agricultural ministry. In the absence of a reliable extension, the lack of strong linkages between farmers and researchers limits communication and exchange on farmer vulnerabilities and needs (Stigter and Winarto, 2012). During this study, agricultural production was hampered by poor farm management and lack of support to farmers. This was observed during transects walks on farms. When we implemented the study it became clear that we were pioneers in learning the farmers on the availability, reliability and application of agrometeorological information/advisories/services for agricultural planning. Therefore, the application of agrometeorology on-farm is a concept that needs to be well-taught to the farmers and other users. Notes recorded in my research diary indicated that poor crop status was a result of lack of communication between the developers and the users of information/advisories/services. Yet, there is lot of well-researched results available on the shelves that can be used by the farmers for better agricultural productivity. The tendency of scientists to develop knowledge for journals in the library that do not reach any end-users should be changed. It is therefore the responsibility of researchers and intermediaries to ensure that farmers have access to quality information/advisories/services for the betterment of agriculture in the Republic of South Africa at large. Therefore, the development of tailor-made advisories/services should be the first priority in creating a learning situation for farmers about environmental conditions for improved decision making towards sustainable agriculture.

3.3The role of agrometeorology

Currently, poor crop status in the study area and other parts of Africa is, among others, a result of the lack of fully operational significant agrometeorological activities (Olufayo et al., 1998; Hoogenboom, 2000). Initiatives (see below Box 3.1) by the National Department of Agriculture, Forests and Fisheries (DAFF) together with the Provincial DAFF to alleviate poverty, increase food production and ensure food security. But as farmers are faced with lot of challenges for the development of sustainable agriculture, their situation is a result of lack of skill in coping with weather and climate conditions and other external factors such as suitable technologies. The most crucial part is that agricultural management strategies have to be tailored to environmental and climatic conditions. Farming systems should be able to accommodate microclimate designs as part of coping strategies. It is unfortunate; however, that climate variability differs for the very same period of planting season from year to year.

Box 3.1 Examples on the initiatives of DAFF. In 2009 the Climate and Risks Information Unit was implemented which is aimed providing agrometeorological services to farmers. Several food security project such as poultry, provision of tractors and other implements, piggery structured , provision of inputs for crop production are ongoing in the south-western Free State. But provision of agrometeorological advisories/products/services may improve the agricultural status in the study area.

Already Fageria (1992) stated more than 20 years ago that about 80% of the variability of agricultural production is a result of the variability in weather conditions, especially for rainfed production systems. The critical more general agrometeorological variables associated with agricultural production are rainfall (onset, intra-seasonal distribution and cessation), temperature (minimum and maximum), and solar radiation. Air temperature is the main weather variable that regulates the rate of vegetative and reproductive development (e.g. Hoogenboom, 2000). Many meetings with the farmers to explain and learn about the use of (scenarios derived from) weather forecasts and climate predictions in agriculture were conducted. While all the agroclimatological parameters were explained to the farmers, it is imperative to note, in a world with global warming, that an increase in temperature causes an increase in the developmental rates. At very high temperatures developmental rates slow down as the temperature further increases. Therefore, during extremely hot days, farmers could consider irrigation to regulate temperature and assure that crops are not exposed to water and temperature stress.

Across the study area participants were provided with weather forecasts on a daily and multi-days basis and with climate predictions on a 14 days and a monthly basis. The various types of forecasts/predictions disseminated as produced by the South African Weather Services (SAWS) were: (i) weather forecasts (now casting (1-6 hours, rainfall and temperature), daily forecasts which include rainfall, temperature maximum and minimum, wind speed and direction, 7 days forecasts (Table 3.6) and (ii) climate predictions (14 days (which is properly divided into four groups >1 mm, > 5 mm, >10 mm, > 20 mm and for the purpose of this study the first two will be used), 30 days and a seasonal (three months) rainfall prediction) . Provision of weather forecasts, as exemplified in Table 3.6, informs the farmers of daily weather conditions. Based on such forecasts the farmer can develop different choices in decision making. For example, July is a very cold month in the south-western Free State, minimum temperatures ranging from -6˚C to 2˚C (Kotzé, 1980, SAWS, 2009). Therefore, frost preventive measures should be considered such as erective frost nets (which is available at Gundlle Plastics), making fire around or inside planted crop fields to regulate temperature, or using plastic tunnels (Stigter, 2010) during this time of season. The maximum temperatures range from 11˚C to 20˚C, therefore, crops that require a high amount of degree days (thermal time) should only be planted in a summer season.

Table 3.6. An example of a 7-days weather forecast for Bloemfontein (SAWS, 2008)

Monday, 7 July 2008		**Tuesday, 8 July 2008**	**Wednesday, 9 July 2008**
Min: 0°C Max: 17°C Discomfort Index: 16°C Weather: Fine. Wind: moderate northwesterly UVB: Dangerous	Sunrise: 07:05 Sunset: 17:26 Moon phase: Waxing Moonrise: 10:10 Moonset: 22:14 Temperature: 4.5 °C Dew Point:-1.7 °C Humidity:64 % Wind: NE, 8.0 km/h (4 Kts)	Min: 3°C Max: 20°C Wind: light NW Sunrise: 07:04 Sunset: 17:26 Moonrise: 10:40 Moonset: 23:12 Moon phase: Waxing	Min: 0°C Max: 11°C Weather: Sunny. Wind: light SW Sunrise: 07:04 Sunset: 17:27 Moonrise: 11:09 Moonset: xxxx Moon phase: First Quarter
Thursday, 10 July 2008 Min: -6°C Max: 13°C Weather: Fine. Wind: light SE but light NE in the afternoon. Sunrise: 07:04 Sunset: 17:27 Moonrise: 11:39 Moonset: 00:08 Moon phase: First Quarter	**Friday, 11 July 2008** Min: -6°C Max: 15°C Weather: Partly cloudy. Wind: light NE but light SW in the afternoon. Sunrise: 07:04 Sunset: 17:28 Moonrise: 12:10 Moonset: 01:04 Moon phase: First Quarter	**Saturday, 12 July 2008** Min: 2°C Max: 12°C Weather: Partly cloudy. 60% chance of afternoon thunderstorms Wind: light SE Sunrise: 07:04 Sunset: 17:28 Moonrise: 12:44 Moonset: 02:00 Moon phase: Waxing	**Sunday, 13 July 2008** Min: 2°C Max: 13°C Weather: Fine. Wind: light SE but light NE in the afternoon. Sunrise: 07:03 Sunset: 17:29 Moonrise: 13:23 Moonset: 02:56 Moon phase: Waxing

Farmers have the privilege to have indications about weather conditions a week in advance. Of course the accuracy is diminishing in the course of time. Chances of occurring rainfall are presented as probabilities or as fine, partly cloudy or overcast. Very importantly, the discomfort index is included in this advisory whenever obligatory (not in Fig. 3.6). The discomfort index estimates the impact of heat stress on the individual, taking into account the combined effects of temperature and humidity (Table 3.7). The discomfort index during the summer season under very hot conditions may increase tremendously. In such conditions the human organism perspires to maintain its temperature within proper physiological limits. The sweat evaporates as a cooling effect on the skin. High humidity levels in the surrounding environment may obstruct the cooling process. Therefore, forecasting information is not only important for farming purposes but as well for the well-being of farmers and farm workers during harsh environmental conditions (*Encyclopedia Britannica,* 2012). The Discomfort Index is expressed by the South African Weather Services as follows:

Discomfort Index = (2 x T) + (RH/100 x T) + 24, Where: T is the dry-bulb or air temperature in degrees Celsius, RH is the percentage relative humidity, This index gives the following degrees of discomfort:

Up to 29 C°	No discomfort
From 30 to 34 C°	Slight discomfort sensation
From 35 to 39 C°	Strong discomfort. Caution: limit the heaviest physical activities
From 40 to 45 C°	Strong indisposition sensation. Danger: avoid efforts
From 46 to 53 C°	Serious danger: stop all physical activities
Over 54 C°	Death danger: imminent heatstroke

Table 3.7. Discomfort index (˚C) as calculated using temperature and relative humidity

	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
42°	48	50	52	55	57	59	62	64	66	68	71	73	75	77	80	82
41°	46	48	51	53	55	57	59	61	64	66	68	70	72	74	76	79
40°	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75
39°	43	45	47	49	51	53	55	57	59	61	63	65	66	68	70	72
38°	42	44	45	47	49	51	53	55	56	58	60	62	64	66	67	69
37°	40	42	44	45	47	49	51	52	54	56	58	59	61	63	65	66
36°	39	40	42	44	45	47	49	50	52	54	55	57	59	60	62	63
35°	37	39	40	42	44	45	47	48	50	51	53	54	56	58	59	61
34°	36	37	39	40	42	43	45	46	48	49	51	52	54	55	57	58
33°	34	36	37	39	40	41	43	44	46	47	48	50	51	53	54	55
32°	33	34	36	37	38	40	41	42	44	45	46	48	49	50	52	53
31°	32	33	34	35	37	38	39	40	42	43	44	45	47	48	49	50
30°	30	32	33	34	35	36	37	39	40	41	42	43	45	46	47	48
29°	29	30	31	32	33	35	36	37	38	39	40	41	42	43	45	46
28°	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
27°	27	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
26°	26	26	27	28	29	30	31	32	33	34	34	35	36	37	38	39
25°	25	25	26	27	27	28	29	30	31	32	33	34	34	35	36	37
24°	24	24	24	25	26	27	28	28	29	30	31	32	33	33	34	35
23°	23	23	23	24	25	25	26	27	28	28	29	30	31	32	32	33
22°	22	22	22	22	23	24	25	25	26	27	27	28	29	30	30	31

Other very important climatic parameters that are taken into consideration during strategic planning for on-farm management are the wind severity and its directions, the amount of sunshine in hours (sunrise to sunset), in other cases the moon phases. Based on forecasting, farmers can develop sound strategic and tactical operational decisions within sufficient time. Examples are when to plough the land, when to plant, to plant seeds or seedlings, when and how often to control weeds, to administer herbicides or pesticides, when to harvest without being disturbed by rains or other agricultural activities, when to cut lucerne and allow the drying and baling process without the interference of rains (since rains can spoil lucerne and cause sour taste and bloating in cattle), when to cut maize for silage processing, and when to shear sheep for wool production.

Farmers were provided with four rain gauges per farm to sensitize them on rainfall recording and handling and use of data. Moreover, three automatic weather stations were installed at selected towns to familiarize the farmers with methods used by agrometeorologists to record climatic conditions. As experienced by Prahara et al., (2011), laying a foundation to improve agrometeorological analysis may not be taken as the simplest task. There are dynamics involved since two domains of knowledge are meeting. These two domains are indigenous and science-based knowledge. The most crucial part was to analyze the rainfall data and explain the consequences. The farmers were given note books to record data and the data sheet was drawn with six columns for dates, the amounts of rainfall recorded (mm), crop status, animal status, agroforestry and other general on-farm observation (Table 3.8). The farmers were also requested to record any other of their observations.

Table 3.8 The format of the data collection sheet used in the south-western Free State

Farm name......., Location......., Farm size......, Enterprises......, Study group....., Contact number....					
Dates	**Amount of rainfall measure (mm)**	**Crop status based on farmers observations**	**Animal status based on farmers observations**	**Agroforestry**	**Action to take or action taken**

Writing was never problematic since most farmers could express themselves eloquently. For a minute group of farmers who were illiterate, members of the family took the responsibility of conducting the recording. During on-farm visits agrometeorologists read remarks as recorded and the discussions were conducted according to the farmers' needs. During the field visits, complex or particular phenomena as recorded and discovered by the farmers in their fields were witnessed. To mention just a few, one was the crop status, whether it was healthy or not. Some fields had pretty healthy crops and other had stunted crop, infestation of insects and diseases, others were touched by an outbreak of locusts, other crops were changing colors from green to yellowish or purplish, other crops showed signs of water stress, long dry days, floods, droughts, the soil had cracks, spacing of crops was not adhered to and there was poor weed control. The farmers experienced difficulties in identifying the causes for abnormalities as mentioned above. For animal farmers amongst others particularities were underweight animals, overgrazed fields, overpopulated stalls, distant drinking water points, dying of calves during delivery, injuries caused by hail to livestock, veld fires and heat stress. For agroforestry farmers it was noted that they experienced problems with unexpected cold days, when frost at flowering damaged the flowers resulting in reduction of fruit production, with deforestation for fuel, with drying of fruit trees, with unproductive trees and with pests and diseases.

At the beginning of the study famers took advantage of the agrometeorologists and raised all their problems, even those that were not related to weather and climate conditions. This is in line with experience described by Winarto and Stigter (2011) in Indonesia. It became also our task to clarify our role in the community. Our role was well understood by the farmers during the stakeholder analysis, rating and ranking. It was very interesting to discover that the farmers actually considered our study very informative and beneficiary to their daily activities. Some farmers took the initiative of developing their own seedlings and understood very well the influence of rainfall and other weather conditions in relation to different crop stages. Mr Cangiso, a farmer practicing mixed farming, wrote in his note book that during days when there were no rains, his Swiss chard got curly and the color turned to yellowish. All these complex phenomena as recorded by the farmers were consolidated and the topics for discussions at workshops were guided by the farmer's observations as mentioned above.

3.3.1Examples from crop production farmers

The overdependence on rainfall for crop production in the south-western Free State and in Sub Saharan Africa as a whole requires more reliable agrometeorological weather forecasts and climate predictions for farmers for their management and coping operations. Increasing climate variability, as a consequence of climate change, under rainfed conditions can have devastating impacts on plant growth and developmental stages, resulting in poor crop yield, worsening poverty and deepening food insecurity. According to Thornton et al. (2007), Thornton (2012) and Thornton and Cramer (2012), the effect of climate change will also have adverse impacts on crop production because of an increased local mean temperature by 1 – 3 °C in the not too distant future. Rainfall distribution plays a big role in plant developmental stages and modifies the whole process of plant growth. During prolonged dry spells drought effects occur, while water logging is experienced during periods of extensive rainfall. Drought occurrences can affect developmental stages positively or negatively, based on the crop development stage. As part of our learning approach during workshops and meetings, farmers discussed different developmental stages. Based on the predicted seasonal conditions, farmers were advised to shift planting dates, change cultivars and observe the weather forecast closely for reduction of crop losses. It may become advisable for farmers to opt for shorter growing season cultivars or to plant drought tolerant varieties. During extensive rainfall events, water logging may occur depending on the type of soils in the area. In this study area most farms were located on high clay soils. During water logging, stress also inhibits water uptake, since the rooting zone becomes 100% saturated with water and this causes a lack of oxygen necessary for root development and respiration.

Crop selection is yet another very important factor in farming systems. Therefore, farmers were advised to select alternative suitable crops derived from crop models. The Ehlers Crop Suitability Zones (ECSZ) system was used in this programme for crop selection. This crop selection system was used to guide agricultural production as a function of weather and soil conditions, with considerations of crop management. Using this crop simulation model, the suitable crops are selected with consideration of temperature requirements. The ECSZ database was developed for South African conditions (Ehlers, 1988). It is used for crop suitability selection using the seasonal temperature requirements of the crop against a predefined zonal seasonal climate index. It is a web-based system that requires the Arc-Map tool from a Geographical Information System (GIS) to draw up maps according to a zonal seasonal climate index.

The Ehlers crop specifications data are available for 400 crops that can be planted in suitable specified zones as described according to this seasonal climate index (Ehlers, 1988). The Ehlers zone model was chosen for its provision of a high number and variety of crops that a user can choose from. Therefore, the farmer can consider a variety of crops to be included in his/her farming system and sequential farming can also be adapted for producing for consumption and/or income generation. According to Vlok and Olivier (2003) these parameters are defined as average temperature and average night temperature. An index is created to accommodate the two temperature definitions based on the two limits in the annual seasonal cycle, summer and winter, The zones are identified by four digits, e.g. 7714. The first two digits represent the summer month's average temperature from December to February and the last two digits refer to winter month's average temperature from June to August (Ehlers, 1988). The temperature takes both the day and the night average temperature into account to identify crops with optimal temperatures within the potential temperature zone. Areas with similar seasonal climate index are identified with the same colors; different colors represent different altitudes and seasonal climate indices. Therefore, this makes it easier to identify the optimal, sub-optimal suitability of crops per zone (Fig. 3.3).

Seven different suitability zones for a wide range of crops were drawn for the south-western Free State. These zones within the catchment are numbered as follows: zone 4614 covers a very small area of Mantsopa Local Muncipality in the far east of the catchment, zone 5714 covers parts of Mantshopa, Naledi and Kopanog Local Municipalities, zone 6714 covers parts of Masilonyana, Mangaung and Kopanong, zone 7714 is the largest zone and covers the western part of Masilonyana, Mangaung and Letsemeng Local Municipalities, zone 7725 covers the south-eastern area of Sol Plaatjie Local Municipality and stretches along the Modder River in the low lying valley region from the west to about 20 km past Koffiefontein town, zone 8815 forms part of Siyancuma and Letsemeng Local Municipalities and zone 8825 forms part of Sol Plaatjie and Siyancuma Local Municipalities (Fig. 3.3).

The outputs from the Ehlers zone database area listed in Tables 3.9 to 3.15 for the south-western Free State. These outputs of suitable crops were incorporated into advisories informing farmers of alternative crops that can be profitable. The south-western Free State region has a wide range of crops that can be used for diversification. Crop selection is a first step towards the development of meaningful advisories. The ECSZ system selects a range of crops for each zone and also classifies each crop as optimal or sub-optimal. The crops as extracted from the ECSZ system were grouped as follows: vegetables, herbs, grain food, oil seeds and fruits. These alternative crops were adopted by most farmers. Some of the crops from the ECSZ system were not accepted by the farmers, such as mango, pineapple and paw-paw. These crops were rejected due to the fact that south-western Free State is a very cold area and semi-arid (Tables 3.11, 3.12), which made farmers doubtful.

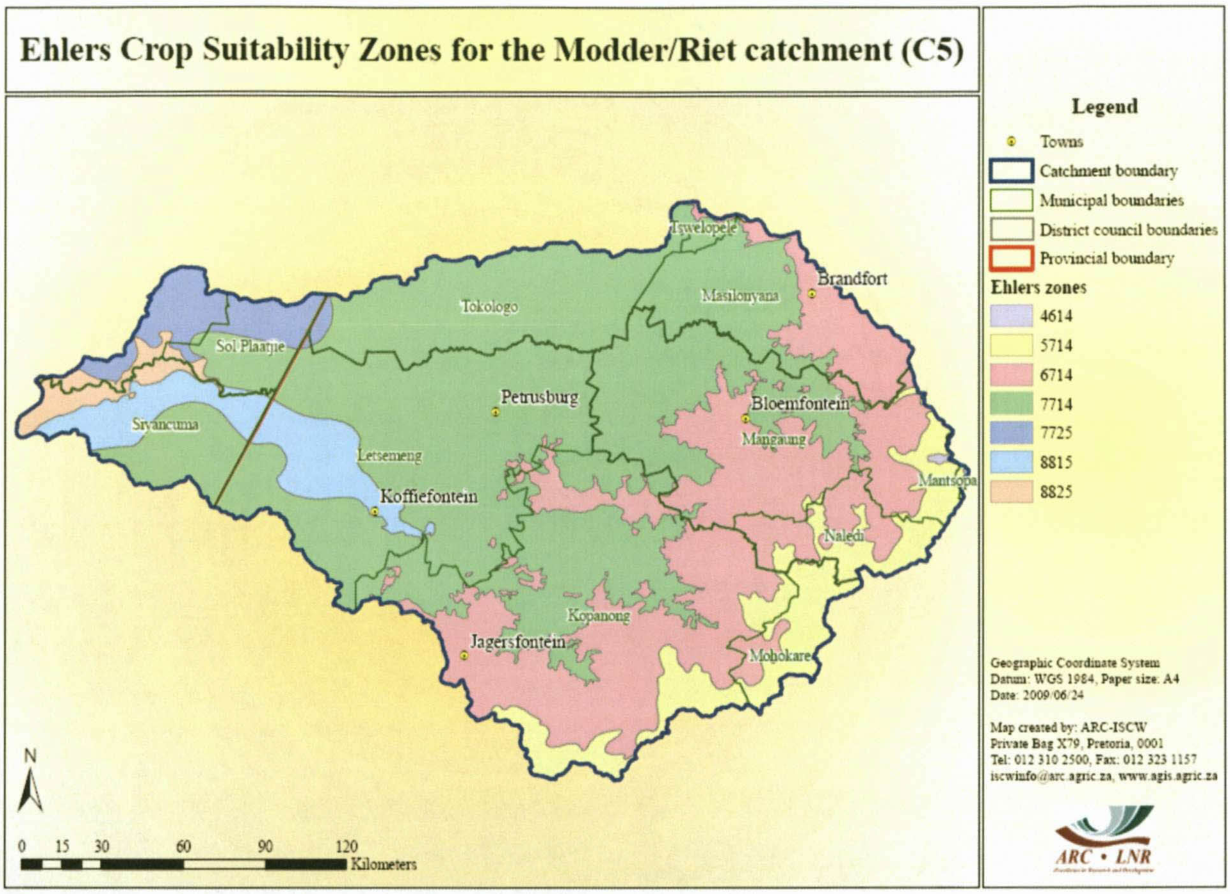

Fig. 3.3 The catchment map showing different zones for alternative crops

Table 3.9 Selected suitable crops for zone 7714 in Modder/Riet Catchment

Season	Vegetables	Herbs	Grain Food	Oil Seed	Fruits
Summer and/or winter	Onion, Garlic, Sweet pepper, Red pepper, Bitter melon, Gherkin, Musk-melon, Soy bean, Tomato, Butter bean, New Zealand Spinach, Bitter Melon	Old-man Bush, Saltbush, Tobacco,	Indian Millet, Winter wheat, Summer wheat, Barley, Maize	Sunflower, Pecan nuts	Pineapple, Guava, Grapes

Table 3.10 Selected suitable crops for zone 6714 in higher ground Modder/Riet Catchment, Hemp is not included in the table.

Season	Vegetables	Herbs	Grain Food	Oil Seed	Fruits
Summer and/or winter	Onion, Garlic, Sweet pepper, Red pepper, Bitter melon, Gherkin, Musk-melon, Pumpkin, Squash, Lentil, Tomato, Big kidney bean, Butter bean, New Zealand Spinach	Dill, Chervil, Old-man bush, Cumin, Basil, Anise, Chicory	Oats (Common) Maize, Barley, Abyssinian millet; Winter wheat	Sunflower, Safflower	Pineapple, Guava, Purple granadilla, Grapes, Apricot

Table 3.11 Selected suitable crops for zone 8815 in Modder/Riet Catchment, Cotton not included

Season	Vegetables	Herbs	Grain Food	Oil Seed	Fruits
Summer and/or winter	Red pepper, Sweet potato, Cassava, Bitter melon, Butter bean, Martynia, and others	Old-man bush, Saltbush, Tobacco, Annatto, Pimento	Rice, Indian millet, Millet	Sunflower, Castor-oil plant, Ground nut	Pawpaw, Mango, Peach, Velvet apple

Table 3.12 Selected suitable crops for zone 7725 in Modder/Riet Catchment

Season	Vegetables	Herbs	Grain Food	Oil Seed	Fruits
Summer and/or winter	Onion, Garlic, Sweet pepper, Red pepper, Bitter melon, Gherkin, Musk-melon, Soy bean, Tomato, Butter bean,	Old-man bush, Saltbush, Tobacco,	Maize, Winter wheat, spring wheat, Indian millet, , Barley	Sunflower, Pecan nuts, Olive	Pineapple, Guava, Grapes.

Table 3.13 Selected suitable crops for zone 8825 in Modder/Riet Catchment fibers have been left out

Season	Vegetables	Herbs	Grain Food	Oil Seed	Fruits
Summer and/or winter	Red pepper, Sweet potato, Cassava, Bitter melon, Butter bean, Bengal bean, Soy bean, Bitter melon	Old-man bush, Saltbush, Annatto, Pimento, Tobacco	Maize, Rice, Indian millet, Barley,	Sunflower, Olive, castor-oil plant, Ground nut,	Pawpaw, Mango, Peach, Velvet apple, Grapes,

Table 3.14 Selected suitable crops for zone 5714 in Modder/Riet Catchment, hemp excluded

Season	Vegetables	Herbs	Grain Food	Oil Seed	Fruits
Summer and/or winter	Onion, Garlic, Celery, Mountain spinach, Chinese cabbage, Celery cabbage, Sweet pepper, Gherkin, Musk-melon, Pumpkin, Squash, Lentil, Big kidney bean, Potato	Dill, Chervil, Old-man bush, Cumin, Coriander, Rocket salad, Sweet cicely, Basil, Anise, Caraway, Endive, Chicory	Oats (Common), Barley, Abyssinianmillet; Teff grass, Rye, Winter wheat	Linseed from Flax(also for fibre) , Safflower	Pine apple, Guava, Apple, Purple granadilla, Japanese plum, Grapes, Mexican hawthorn

Table 3.15 Selected suitable crops for zone 4614 in Modder/Riet Catchment fibers not included below

Season	Vegetables	Herbs	Grain Food	Oil Seed	Fruits
Summer and or winter	Onion, Garlic, Celery, Horse radish, Mountain spinach, Chinese kale/ cabbage, , Rape, Italian broccoli, Collard, Celery cabbage, Potato, Spinach, Oyster plant, Broad bean, Japanese radish, Radish, Lettuce, Lentil, Artichoke, Carrot, Big kidney bean, Common garden pea, Endive, Sweet anise	Dill, Chervil, Field mustard, Black mustard, Coriander, Sweet cicely Parsnip, Parsley, Chicory, Rocket salad, , Caraway, Cumin	Abyssinian millet; Teff grass, Rye, Buckwheat, Oats(Common),Winter wheat	Field mustard (oil), Brown mustard (oil), Cole. Cole-seed (canola), Rape cole (canola), Flax (linseed) Mexican hawthorn	Strawberry, Apple, Plum, Japanese plum, Sweet cherry

During field visits agrometeorologists observed that the crop status with (mostly) resource poor farmers was poor in comparison with that with commercial farmers in season 2008/2009. For this season the rainfall prediction was "above normal" the good rains started in December/January.

Advisories were developed to guide the farmers based on the seasonal conditions for 2009/2010, whereby for October-November-December (OND), November-December-January (NDJ) the rainfall predictions were below-normal, but for January-February-March (JFM) above-normal rainfall was expected. These advisories were on crop type selection, cultivar selection, planting date selection and management strategies. The advisory recommended that the farmers should strictly consider late planting, preferably within the last week of December 2009, following the 14-days prediction prior to engaging to agricultural daily activities. The best scenarios given to the famers under early below-normal but late above-normal rainfall conditions were to consider planting cultivars with short maturing times, increase plant population and control weeds more often. However, not all farmers took heed to delayed planting, For example, Mr Mokhethi in Sannaspos planted on 30 November 2009 and harvested only 1-2 ton/ha and Mr. van Tonder planted on 27 December 2009, three days before the actual onset of rainfall, and in July 2010 he harvested 2-3 ton/ha. They were both under rainfed planting. (see also Appendix 1A)

Another example worth mentioning is that when agrometeorologists started working with Mr. Ncangiso while he was producing Swiss chard at only 14 m^2. He increased his land allocated for crop production from 14 m^2 to 4 ha. Moreover, he introduced winter cabbage and herbs. He constantly checked the weather forecasts and climate predictions. He decided to invest on an irrigation system, that was installed in a 2 ha area, to irrigate the sequential planting he adopted. Mr. Ncangiso's 1st planting was in the 2nd week of July, where he planted 15.000 plants/0.5ha of Swiss chard, 2nd planting took place in the 2nd week of September with 15.000 plants/0.5ha, the 3rd planting was in the last week of November whereby he planted 20.000 plants/0.5ha and the last planting was done in the last week of December when 35.000 plants/ha were transplanted. Mr. Ncangiso realized that the plants planted in September had suffered frost burns, which were caused by the black frost that occurred within the second week of July 2008 just after planting. The frost chart was also explained to assist on selecting frost free days (Appendix 1.4). During the on-farm visits Mr. Ncangiso always invited his workers to partake in our discussion to learn the scientific way of decision making. A recommendation was also made that he should buy a frost protection net as this could allow him to produce Swiss chard throughout the year, without running into frost damages. During the reflection phase when agrometeorologists visited Mr. Ncangiso in April 2010, he appreciated the availability of the weather forecasts, climate predictions and the support service from intermediaries as he increased his income and was able to harvest rotationally without running out of Swiss chard. In April 2010 he had raised enough money to buy cabbage and onion seedling where he planted 36.000 plant/ha of cabbage and 40.000 plants/ha of onion during the winter season (see also Chapter 4 where the story has been intensively explained).

A shift from only using traditional knowledge was observed by agrometeorologists since during discussions at workshops and on-farm visits; famers were more interested to discuss agrometeorological information/advisories/services. This was the farmer's choice as the farmers were encouraged to make use of both indigenous and scientific rainfall forecasting. During interaction with the farmers, we noted successful use and limitations of local traditional knowledge as well as scientific knowledge. The request for agrometeorological information/advisories/services increased. These farmers were taught well on how to interpret rainfall maps and on the application of rainfall information for on-farm decisions. Limitations were due to methods of information dissemination since most farmers have no access to e-mails and internet. Also the district intermediaries or extension officers were not well skilled in using weather forecasts and climate predictions to create advisories/services. However, after all, the availability of weather forecasts and climate predictions to all types of farmers made noticeable changes in their decision making and improvements in their management practices (see also Chapter 4).

3.3.2 Examples from animal husbandry farmers

Small and large livestock farmers were identified during the diagnosis stage of the research programme of our study. Such farmers were involved in pig farming, poultry farming, sheep farming, goat farming, cattle and horse farming. There is a huge increase in public demand for animal products for local consumption in Africa (Nardone, et al., 2010). But, as also indicated elsewhere in this thesis, currently, worldwide a scourge of climate change has been documented by farmers and scientists alike. This causes noticeable shifts in local climate conditions, resulting in severe impacts on local agriculture. More frequent warm spells, heat waves, heavy rainfall have been estimated to reach confidence level >90% (IPCC, 2007). The effects of changing climate conditions on soil erosion and fertility, on water scarcity, on grain yields and quality reduction, on outbreak of diseases and insect pests will also weaken animal production.

In the south-western Free State, under mixed farming systems manure is used for fertilizer on cultivated land to improve soil nutrient status. Adverse climatic conditions such as lower rainfall, more frequent dry spells and droughts as well as heat stress not only negatively influence animal husbandry directly but also have an impact on crop and pasture production which indirectly affects animal growth. Therefore, provision of agrometeorological information/advisories/services will assist to make decisions that favor the increase of stock productivity per head and improve the sustainability of animal production. As an example, an appreciable number of cattle and sheep were recorded dead during the above-normal rainfall season in 2009/2010 in the Free State province of South Africa, as a result of a vector borne disease called rift valley fever. Should the farmers have known forecasted and predicted weather/climate conditions and would they have received timely advisories, they would have been able to vaccinate their stock and to relocate animals from near wetland areas, swamps and salt pans.

3.3.3 Examples from agroforestry

It is also important to discuss the role of agroforestry in agriculture. Agroforestry is the association of trees with farming practices. It is the art and science of cultivating woody perennial plants such as trees in association with crops and/or animals (Kinama et al., 1995; Torquebiaua, 2000; Stigter, 2010). Agroforestry is known as an archetype of traditional agriculture. According to Molua (2005), agroforestry is a form of sustainable land use that combines trees and shrubs with crops and/or livestock in ways that increase and diversify farm and forest production while also conserving natural resources. It is an intensive land management system that optimizes the benefits from the biological interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock. And these days we also look at the positive carbon sequestration involved (e.g. Stigter, 2010)

The countrywide deforestation and increasingly intensive use of land to sustain a growing population has increased soil erosion, scarcity of tree products and environmental degradation, it has lowered soil fertility, and therefore reduced agricultural productivity (Neupane, 2002). Agroforestry is considered a sustainable agricultural system. Therefore it is being widely promoted all over the world but especially in sub-Saharan Africa (Thangata and Alavalapati, 2003). Agroforestry and the complex relationships between agriculture and forestry indicate a common perception that agroforestry is closer to agriculture than to forestry (Torquebiaua, 2000). Field experience indicates a structural classification of agroforestry which is divided into different categories as follows: crops under tree cover, agroforests and agroforestry in a linear arrangement, animal agroforestry, sequential agroforestry and minor agroforestry techniques (Table 3.16). These tabulated categories are necessary to identify different structures that exist in the concept of agroforestry.

Torquebiaua (2000) and Stigter et al. (2005) state that agroforestry advantages can be described as the provision of multiple products (e.g. food, wood, fodder, mulch, fibers, medicines) and services (e.g. soil fertility maintenance and erosion control, microclimate improvement, biodiversity enhancement, watershed protection) by the trees. For example, most farms and farm houses and animal shelters are surrounded by different types of trees such as Eucalyptus, Blue gum, Wattle, Acacia and other types of trees. These trees are used as shelterbelts, windbreakers as well as for inter-cropping and for animal shade. Agroforestry constraints mainly concern potential competition between trees and crops for water, light and nutrients as well as for farm resources such as land or labour. Integration of trees with agricultural activities comprises of well-established farming practices which have been widely studied for the past three to four decades. For example the parklands of Africa are considered "the largest single agricultural land use in sub-Saharan Africa" (Vandenbelt, 1990). Yet another example of agroforestry is the grazing of animals in plantation forests as well as the herding of animals in rangelands with more or less dispersed trees (Von Maydell, 1987; Stigter, 2010).

Table 3.16. Classification of agroforestry in structural categories (adopted from Torquebiaua, 2000).

Crops under tree cover	scattered trees in cropland, shade trees in plantation crops, parklands, crops in orchards, plantation/crops combinations
Agroforests	agroforestry home gardens, village forest gardens, mixed woodlots, agroforestry buffer zones
Agroforestry in a linear arrangement	windbreaks and shelterbelts, boundary planting, live hedges, living fences, soil conservation hedgerows, alley cropping, roadside planting, woody strips
Animal agroforestry	grazing or browsing in wooded or forested land, tree planting in rangeland, animal feeding with collected browse, browse banks
Sequential agroforestry	shifting cultivation, tree-improved fallows, taungya
Minor agroforestry techniques	Sericulture, lacquer production, apiculture with trees, tree-based aquaculture

The farms and households for the study were selected during the inception of the programme or during the diagnosis phase of the research programme. The area selection was based on the motives to assess the feasibility of agrometeorological information/advisories application for agricultural practices with agroforestry. These farms or households were randomly selected for questionnaire surveys. In this questionnaire, agroforestry related questions were incorporated to assess the farmer's perceptions and their agroforestry practices in the selected study area. Amongst all interviewed farmers, agroforestry formed part of their farming systems. Examples are perennial trees that are used for shades for animals, using trees planted where cash crops are planted, or fruit trees and other indigenous types of trees used for fuel. Therefore agroforestry in the south-western Free State forms an integral part of the farming systems. Agroforestry is also delivering part of supplementary sources of food, fodder, fuel-wood and timber by maintaining some naturally grown trees on farmlands. There is a continuous tradition in the south-western Free State of mixed inter-cropping of fruit trees, exotic trees with grains and vegetables (Stigter, 2010).

Chapter 4

Impact Assessment of the Application of Weather Forecasts and Climate Predictions and other Science-based Weather and Climate Information

4.1 Introduction

"Only if it would rain" is the sentiment uttered by all farmers in the south-western Free State during the study period as winter season ceased and the preparations for the growing season were at hand. Deficient topsoil water content at planting may impede or degenerate the process of germination, leading to low plant populations density. Drought is defined on the basis of the degree of dryness and the duration of the dry spell. Water in hydrologic storage systems is often used for irrigation or to supply water to animal drinking points. Climate is a primary contributor to hydrological drought (Palmer, 1965; Fowler & Kilsb, 2002; Bates, et al., 2008; Lotfabadi and Mohamadian, 2010; Zarafshani, et al., 2012).

In many parts of the world, water demand has increased due to population growth and expansion of the agricultural sector (Bates et al., 2008). Also increase in temperature results in more water demand by crops and crops may become susceptible to new or additional infestation of pests and diseases. Increase in temperature results also in heat stress in dairy cows which can lead to weight loss, poor feeding and reduced milk production. Poor production may be expected in fruit trees since a required minimum number of low temperature hours are crucial for the budding process.

Freezing injuries to fruit trees are linked with low temperatures preceding dormancy in autumn, in midwinter during dormancy, but in particular during and after bud break in the spring (Rodrigo, 2000; Whaley, et al., 2004). Whether ice formation occurs either extra-cellular or intra-cellular, it is fatal and causes cell death (Rodrigo, 2000; Whaley, et al., 2004). Farmers need a frost related weather forecast to apply frost preventative measures which protect the crops from damages or appreciably diminish them. This work contributed at developing and disseminating tailor made advisories on different types of agrometeorological information/advisories/services (see Chapter 3). Given challenges faced by the farmers which are weather/climate related, the importance of impact assessments of the application of agrometeorological information/advisories/services remains crucial.

Farms and projects that were awarded to the farmers in the south-western Free State, to be specific, were largely lacking an integrated approach. Most farmers owned land but could not cultivate the land due to high input cost, lack of farm management skills and knowledge on the application of weather forecasting, climate predictions and other science-based weather and climate information. Therefore, this project was aimed at bringing knowledge to the farmers on the benefits of the application of agrometeorological information/advisories/services.

4.2 Specific challenges for south-western Free State farmers

The sustainability of commercial and resource poor farmer's livelihoods is very delicate and unstable. Therefore, it is imperative to consider this delicacy. The impact of development initiatives needs to be assessed in this context. Basically the development initiatives for agricultural sustainability should allow farmers to become in a position to preserve natural resources. To be able to develop viable initiatives, need analyses from farmers is one most important factor (e.g. Winarto & Stigter, 2011). During the descriptive stage of this study, participatory tools were used to identify their needs. Farmers faced weather and none-weather related challenges that hindered successful productivity. To contribute to the improvement of sustainable agricultural productivity and livelihoods, it is necessary to address the following types of needs, felt by the commercial and resource poor farmers in the south-western Free State:

- ✓ more secure access to and better management of natural resources
- ✓ more secure access to financial resources
- ✓ improved access to suitable agricultural technologies and information
- ✓ more support from extension agents and agricultural ministries
- ✓ understanding different stakeholders involved in agricultural development
- ✓ access to agrometeorological information/advisories/services and other science-based information
- ✓ speedy processes for obtaining land
- ✓ rehabilitation and installment of irrigation systems on farms
- ✓ transportation of agricultural products and access to markets
- ✓ support in obtainment (or subsidies for) farm implements
- ✓ mentorship and training on farm management skills
- ✓ sequential planting to meet market demands
- ✓ Eradication of animals roaming around the residential areas
- ✓ control of wild animals that destroy maize and wheat in some areas
- ✓ fencing of farms

In this context, it is a necessity to go further than evaluation of research performance in terms of agrometeorological advisories/products/services delivered and related decisions made by the farmers. Agricultural advancement is as much a social, political and institutional process as a technological one. For this reason, other stakeholders' perceptions and efforts are required, as perceived, understood and appreciated by farmers, for successful decision making. This agricultural research study was therefore designed and carried out within an integrated or holistic livelihoods framework. To empower farmers on the application of agrometeorological information/advisories/services for sustainable agricultural productivity, impact assessment should examine how generated agrometeorological knowledge is being made client friendly, disseminated/transferred and ultimately used and how this use positively affects farmers' livelihood and that of their neighbors. This study was essential to facilitate the process of information/advisories/services dissemination developed specifically for the farmers and to identify the channels of dissemination.

Farmers in this study area felt and expressed their problems as listed below.

- ✓ Lack of water and rainfall scarcity
- ✓ Notable rainfall variability
- ✓ Devastating drought conditions
- ✓ Severe and untimely frost occurrences with damaging effects
- ✓ Damaging hailstorm
- ✓ Very strong winds
- ✓ Horrifying lightning incidents
- ✓ Ravaging wildfires during winter months
- ✓ Outbreak of pests and diseases
- ✓ Drying of rivers, reservoirs and boreholes
- ✓ Onset of rains and frost coming earlier or later than usual (see also Chapter 3)

4.3 Can agrometeorological information be of benefit?

This question was already positively answered in earlier chapters. In one more presently upcoming example, the study conducted by Orlandini et al., (2008) confirmed that climatic parameters may be used as inputs for modelling to determine any possible behavior differences in the pathosystem, to be used as a predictive tool for the disease outbreak. For this approach see further Stigter and Rathore (2008). Therefore, it is crucial for agrometeorologists/-climatologists to thoroughly have farmers trained on the application of agrometeorological information/advisories/services for successful and sustainable agricultural productivity. For such an approach, see Stigter & Winarto (2012).

4. 4 Farmer training

As part of the assessments, of the acceptability and the adaptability of agrometeorological information/advisories/services, comparisons were conducted amongst farmers who were trained and non-trained to use weather forecasts/climate predictions and other science-based weather/climate information. This is discussed below. Training of farmers took place in study groups, and follow ups were conducted during on-farm visits. The strategy to implement on-farm visits was developed through the observation that study groups combined solutions to diverse needs of farmers. On-farm visits were designed to address particularly the challenges as experienced by that/those farm owner(s). Therefore, experts from agrometeorology discipline participated in farmer training. The experts who trained farmers on a wide range of topics were identified from the University of the Free State, Department of Soil, Crop and Climate Sciences, Agricultural Research Council, Agri SA, South African Weather Services and Financial Institutions.

These trainings addressed selected aspects of agrometeorology such as interpretation of weather forecasts and climate predictions and their consequences for selection of suitable crops and cultivars and for selection of planting dates. Hence, group lessons were generated and compiled according to the needs of the farmers to support agricultural decision making in activities to undertake. The farmers were trained to understand the concept of soil-plant-water-atmosphere interactions. Provision of such training assisted on-farm decision makers to act decisively for reduction of risks and disasters in agricultural productivity but also to make use of windows of opportunities (e.g. Stigter, 2008), as several examples in this thesis have illustrated.

The training of farmers occurred during design and planning stages (Fig 1.3) of the study which are also referred to as the second phase of the study. The training process started during inception workshops in 2008, while researchers were introducing the study objectives to farmers across the study area. For example, different presentations were prepared and delivered to the farmers. A main topic was conservation agriculture, also known as Farming God's Way, introduced by encouraging farmers to plough the land in a most minimal way as possible for the retention of soil water and micro-organisms in the soil. We also encouraged the farmers to preserve crop residues on areas of cultivation and not burn anything. We explained that burning of residues results in lack of cover and therefore in soil erosion, whilst reserving crop residues on land aids soil fertility and retention of soil water content by reduced evaporation and run off as well as control of weed growth (e.g. Flessa et al., 2002).

Farmers were also learning on frost formation and preventative methods against crop damage caused by frost as well as on the utilization of thermal time (degree days) for crop type and crop cultivar selection. Other topics, based on the monthly plan, were continuously covered during interactions with the farmers (Table 4.1). Examples are the agrometeorological concepts for different agricultural enterprises, suitable timing for the execution of agricultural activities, land preparation, tractor maintenance and intensive training on maize production since most farmers were involved in such production.

Table 4.1 Various topics and monthly plans as discussed during farmer workshops in 2008.

Dates	Plans for workshop training 2008
February	Application of weather forecasts/climate predictions advisories to agriculture
March	Field crop observations and harvesting for maize producers farmers
April	Experts visit to present agrometeorological information.
May	Farmers planted cabbage and onion for winter season.
June	Forecasts interpreted by farmers. Farmers presented their plan for 2009/10 planting season. Response farming (response actions) and forecast products updates. Identify suitable methods of dissemination.
July, August and September	Testing of methods of dissemination (as different farmers preferred different methods of dissemination). Advisories entailed (Crop and cultivar selection, planting dates, application of weed control chemicals, insecticides and herbicides, rainfall distribution, tillage methods)
October	Training of intermediaries
November	Final workshops reviewing farmer's plan of action, crop selection, and seasonal forecasts as to dry spell probability information.

Therefore, the tactical and strategic operational planning stages of this study laid the foundation for researcher-farmer interaction aiming to integrate weather forecasts/climate predictions and other science-based agrometeorological information for daily farming decisions making. Planning entailed different scenarios as required by each agricultural enterprise. The study continued to utilize participatory tools to implement and assess the decisions made by the farmers. During operational planning the farmers were encouraged to incorporate both traditional knowledge and science-based information for planning and decision making. Continuous planning as the project progressed was guided by the challenges and needs of the farmers. An iterative method was used to review the impacts of the decisions taken during the planning process. The duration of the decision making process lead to development of different scenarios for alternative choices. These scenarios were guided by the needs of the farmers in crop production, animal husbandry and agroforestry. Because farmers were a hugely diverse community in terms of challenges and interests, the planning process had to be directed to these specific interests of the farmers.

Since there are farmers who are actively involved in systems reliant on rainfall as the only supply of water for crop and pasture growth, seasonal rainfall variability is certainly reflected in highly variable production levels with notable livelihood effects. But this seasonal rainfall variability also shows farmer needs for weather forecasts and climate predictions to be integrated into the decision making. Monthly/seasonal rainfall predictions are categorized as normal, below normal or above normal rainfall conditions see also Chapter 2. Prediction of one of these categories is an indication for farmers to plan for a dry, normal or wet month/season. This information guides the farmer to plan accordingly.

The individual farmers within the study groups were assisted to develop a suitable strategic plan according to their needs per farm or per agricultural enterprise. At the meeting farmers with similar agricultural enterprises and interests were grouped together for brainstorming during the drafting of the strategic plan. An example of a seasonal planting plan for maize producers for across the study area is presented in Table 4.2. The farmers were encouraged to come up with different scenarios as alternatives for mitigation and intervention strategies. The strategies developed by the farmers included the selection of suitable planting dates and crop cultivars, considering the monthly/seasonal prediction concurrently with the weekly forecasts and the 14-days predictions. Given predictions for October, November and December 2008, farmers were encouraged to plant in the first week of January 2009. This process resulted in development of a comprehensive implementation plan, for the season ahead, for each farm. The implementation plan was essential to prepare the farmers on the following questions (Table 4.2): What? Where? When? How? Who?

Other questions remained to be addressed simultaneously. Who can provide good advice? How can we do this differently or better to improve crop production and minimize the risks? Where to get more information that may guide decision making. This process facilitated action planning and valuing other suggestions from other participants. A review plan for action was compiled after each and every decision was made and changes were included for a new planting plan.

Table 4.2. The seasonal planting plan for maize producers for 2008/09.

What?	Where?	When?	How?	Who?	Outputs
Prepare implements	To the dealer for service	June-July	Ensure that it is ready for land preparation	Farmers	Implements ready for land preparation
Land preparation	EMS farm, van Tonder farm, Woonhuis farm, Scots & Sons farm, Mokheledi farm	Last week of July	Cultivate when soil is moist enough to kill weeds	Farm owners	Land prepared on time
Take soil samples	From field to be planted	July before soil cultivation	Use a spade or an auger	FSDoA Glen soil analytical services	Soil status known for fertilizer application
Place order and buy inputs	Suppliers	August and September	Ensure that all inputs are bought	Farm owners	Inputs ready before planting
Disc the land	van Tonder and Scots & Sons farm	First week November	To prepare for planting	Farm owners	Land prepared
	EMS farm, Woonhuis farm, and Mokheledi farm	Last week of October to first week of November	To prepare for planting	Farm owners	Land prepared
Planting	EMS farm, van Tonder, Woon huis, Scots & Sons farm, Mokheledi farm	From 15 Nov. to 15 Dec. (1st plant date) 20 Dec. to 10 Jan. (2nd plant date)	Using a planter drawn by a tractor. Put recommended fertilizer per field at planting	Farm team	Land planted on selected dates
Weeding	All producers	When weeds infest	Spraying chemicals, hand hoeing, tractor	Farm team	Weeds controlled frequently
Fertilizers	All producers	At six weeks or beyond or just before good rains	Top dressing	Farm team	Fertilizer applied accordingly
Pesticides	All producers	Observe insects manifestation	Spraying	Farm team	Pests control actions
Harvest	Scots & Sons farm	At maturity while green for silage	Cut maize plants from bottom node	Farm team	Harvested for silage
	EMS farm, van Tonder, Woon Huis, Mokheledi farm	Cobs ready for consumption	By hand	Farm team	Harvested for fresh green maize
	EMS farm, van Tonder, Woon Huis Scots & Sons farm, Mokheledi farm.	Grains are well filled and dried out	By hand and a harvester	Farm team	Harvested for grain and ready for market
Request agrometeorological information	Agricultural Research Council	Weekly basis	Telephone, e-mail and during study group meetings	Researcher	Timely receipt of information

Another operational plan was prepared by Mr. Ncangiso, a Swiss chard producer (Table 4.3). He had planted ¼ ha for two seasons before the inception of our workshop. Suggestions were made to him to expand his size of plantation and that he may adopt serial planting of Swiss chard for continuous market supply. The other recommendation was to erect frost nets for frost damage prevention. (see also to other sections in Chapter 3 where Ncangiso is indicated).

Table 4.3 Example of Swiss chard planting plan by Ncangiso for 2008/09.

What	Where	When	How
Request weekly and 14-day forecast	Agricultural Research Council	Every Monday	Collect it from office, telephone or SMS
Take soil samples	FSDoA Glen Soil Analysis Laboratory	July	Auger
Land preparation	Woon Huis	Last week of July	Using a plough
Prepare seedlings and place an order	On farm, Kwaggafontein nursery	Last week of August	Cover the planted area with grass and plastic until ready to be transplanted
Fetch the seedlings from nursery and transplant	Plant 15 000 seedlings in ½ ha	First week October	Manual planting
2nd Transplant	Plant 15 000 seedlings in ½ ha	First week November	Manual planting
Control weeds and insects	Infested planted sites	When damage noticed	Round up
3rd Transplant	Plant 30 000 seedlings in 1 ha	15 December 2008	Manual planting
Control weeds and insects	Infested planted sites	When damage noticed	Round up
4th Transplant	Plant 34 000 seedlings in 1 ha	10 January 2009	Manual planting
Harvest successively (the 1st harvesting occurred after 6 weeks and continuous harvest on weekly basis).			

Execution of plans developed by the farmers brought positive results for all farmers that participated since there was a noticeable increase in production for seasons 2008/09, 2009/10, 2010/11 and 2011/12 (description of the farmers before 2008/09 is given in Appendix 1A and Table 4.4). A few successful stories of farmers using the weather forecasting/climate predictions were identified within the study area. For example, the rainfall forecast for season 2008/2009 predicted above-normal probabilities of rainfall for January, February and March 2009. This above rainfall was received. Farmers were decided to select a cultivar of maize with a short growing season, to be planted during 1st week January at a high plant density and they produced 2-3tons/ha of rainfed maize, which was higher when compared with farmers who planted earlier or later than the given date (refer to Chapter 3).

Table 4.4 Few selected examples of farmers who had noticeable yield increment

Example	Season 2008/09	Season 2009/10	Season 2010/11	Season 2011/12	Turnover per year (R)
Titapoho Farm	Diverse agricultural enterprises	Focus on bee-keeping, broilers, Swiss chard under protecting nets	Introduced Olive trees	Adopted agroforestry practices	600 000
Van der Merwe	Maize yield (2-3tons/ha) 180 ha	Maize yield (3-4 tons/ha) 165 ha	Maize yield (3-4 ton/ha) 180 ha	Maize yield (4 ton/ha) 180 ha	±750 000
EMS	Maize yield (0 ton/ha) 50 ha	Maize yield (3 tons/ha) 22 ha	Maize yield (2-3 tons/ha) 45ha	Maize yield (2-3 tons/ha) 70 ha	±350 000
Woon Huis	Swiss chard (300 bunches	Cabbages, Swiss chard, onion	Cabbages, Swiss chard, onion, herbs	Cabbages, Swiss chard, onion, herbs	±160 000
Lentoro	Wheat yield (3tons/ha) 40 ha	Wheat yield (3tons/ha) 80 ha	Wheat yield (3tons/ha) 120 ha	Wheat yield (irrigated)(3tons/ha) 40 ha	±200 000
Vula Africa	Wheat yield (1tons/ha) 25 ha	Wheat yield (2tons/ha) 25 ha	Wheat yield (irrigated)(3tons/ha) 25 ha	Wheat yield (irrigated)(3tons/ha) 55 ha	±105 000
Khume Farm	Lucerne (50ha), Eragrostis (78)	Lucerne (50ha), Eragrostis (78)	Lucerne (50ha), Eragrostis (78)	Lucerne (50ha), Eragrostis (78)	±175 000
KFN Broilers	100 broilers Peach trees	200 broilers Peach trees	1000 broilers Peach trees	1000 broilers Peach trees	±1 100 000
Glen Farm	Silage & Lucerne for dairy cattle 15 ha	Silage & Lucerne for dairy cattle 40 ha	Silage & Lucerne for dairy cattle 40 ha	Silage & Lucerne for dairy cattle 40 ha	± not given
Morogo Veggies	Cabbage, carrots, Swiss chard ½ ha	Cabbage, carrots, Swiss chard ½ ha	Cabbage, carrots, Swiss chard 5 ha	Cabbage, carrots, Swiss chard 5 ha	±60 000
Thebeagae	Sunflower, maize, piggery, sheep	Sunflower, maize, piggery, sheep	Sunflower, maize, piggery, sheep	Sunflower, maize, piggery, sheep	±160 00
Van Tonder	Maize yield (3 tons/ha) 25 ha	Maize yield (3 tons/ha) 40 ha	Maize yield (3 tons/ha) 40 ha	Maize yield (3 tons/ha) 40 ha	±200 000

Another example is for season 2009/2010 the prediction showed below normal rainfall conditions for September, October, November and December. Drought tolerant crops were the best option for producers. For example Mr. Mokgothu and Mr. Mokhethi decided to plant sorghum as they can use it to feed livestock. From January to March the prediction was for above-normal rainfall conditions. The maize farmers were therefore advised to plant early January to get most benefit and utilize the forecast of good rainfall. At this stage of the project the farmers had gained confidence in the forecasts/predictions and they had learnt to use long term predictions concurrently with the short term forecasts. As a result, maize producers planted late December 2009 just before rainfall onset. These farmers produced 2.5-3tons/ha and residues were dried to feed livestock for the winter season. The vegetable farmers ensured that their seedlings were well established by the first week of January 2010, as the 14 day rainfall prediction confirmed good rainfalls as also earlier predicted. Mr Mokheledi mentioned that about 40% of his Swiss chard and cabbage seedlings died due to water logging because he had planned to plant on 20th January 2010. He also confessed that Swiss chard and cabbage plants planted on the 15th December 2009 under irrigation did well during January 2010 as the plants were already well established; Mr. Ncangiso experienced the same problem in only one field and after rains the crops recovered and were ready to harvest.

A short-term weather forecast may provide a good indication of the day or week to receive rainfall. This information guides the farmer on whether to engage into field operations or not. During the implementation phase, together with continued listening to the weather forecast, farmers kept on reflecting on decisions made. Mr. Gwili, a farm manager at Glen farm, collected daily weather forecasts and 14 days weather predictions on a daily basis from ARC-ISCW Glen office, as available from agrometeorological personnel, to make guided decisions. He once looked at the rainfall probabilities and found that there was 60% chance of rainfall in the coming week. He decided not to cut Lucerne as it could become fermented. If the cattle consume such products, bloating takes place. Dry days are favorable to cut and dry lucerne and in about 14 days it is baled.

Other farmers organized laborers for weeding when the short term forecast predicted prolonged dry spells. Again other farmers arranged for water pipes to draw water from Modder River to irrigate Swiss chard. While rainfall forecasting/prediction is fundamental to on-farm decision making, this shows that in fact the rainfall distribution from onset to cessation is important, but neither weather forecasts nor climate predictions are able to furnish data on that distribution well in advance. Farmers who continually attended monthly meetings and who used agrometeorological advisories had better yields compared to past seasons as well as compared to farmers who had no exposure to advisories. For example, Mr. Mokhethi, EMS farm, improved his maize yields from 0 ton/ha in 2008/09 season to 2 tons/ha in 2009/10, 3 tons/ha in 2010/11. As mentioned already several times as an example, Mr. Ncangiso (Table 4.6) adopted serial planting for Swiss chard production and was able to supply the market continuously throughout the year (see also above). The farmers were continuously encouraged to observe the forecasts/predictions and changes occurring in the field and keep records of abnormal and strange occurrences. During the existence of prolonged dry spells, farmers were encouraged to weed frequently and introduce mulch for soil water retention and weed suppression. One of the most crucial coping systems was for the farmers to act promptly against actual changes observed in the field. An example is application of supplementary irrigation during observed symptoms of water stress to avoid crop failure. Provision of monthly/seasonal weather forecasts (outlook scenarios) assisted farmers to plan in advance and with better understanding of the gross rainfall distribution conditions within the season (of course still on a very simple probabilistic basis).

Farm households are subjective to make certain adjustments in their choices of technologies, of support information and of types of farming production. These coping strategies can be grouped into three categories:

a) options such as choice of drought-tolerant varieties, planting density, cropping systems and investment in water management
b) in-season adjustment of crop and resource management options in response to specific climatic shocks as they evolve, and
c) options that minimize livelihood impacts of adverse climatic shocks.

In the period of early interactions with the farmers, we found a relevant matrix in partly older but still relevant publications on agricultural coping systems (Cooper et al., 2008; Matlon and Kristjanson, 1988), which describe coping strategies in the semi-arid tropics of West Africa (Table 4.5). This matrix was adapted to generally clarify the diversity and variation of coping strategies from farmer to farmer. This shows why farmer and farming system differentiation is the real issue of agrometeorological alternatives in scenarios for agrometeorological services under conditions of a changing climate (Stigter, 2008).

Table 4.5 Coping strategies used by farmers in West Africa (Matlon and Kristjan, 1988)

Scale	Before the season	During the season	After the season
Plant	Variety selection for stress tolerance / resistance	Replanting with earlier maturing varieties	
Plot	Staggered planting dates Low density planting Intercropping Run-off management Delayed fertilizer use	Changing crops when re-planting. Increasing or decreasing plant density at re-planting or by thinning	Grazing of failed plots for animal maintenance
Farm	Diversified cropping Land type diversification Plot fragmentation	Shifting crops between land types	Late planting for forage
Household, Village, Region,	Cereal stocks Livestock/assets Social and Off-farm employment networks	Matching weeding labour inputs to expectations of the season	Asset sales for cereal purchases Food transfers Migration employment

Adaptation of new technologies and information is dependent on the adaptive capacity of the farmers/farming systems, based on production means. It is also highly dependent on livelihood assets namely (i) Natural capital, (ii) Social-political capital, (iii) Human capital, (iv) Physical capital and (v) Financial capital (DFID, 1999). Farmers with a strong asset base are the ones with greater adaptive capacity for sustainable agricultural production and secured livelihoods. Commercial farmers in the south-western Free State could much more easily adapt to new changes and adopt the consequences in comparison to resource poor farmers, since they are more capitalized. The integration of timely, accurate and reliable weather forecasts and climate predictions may become a central part in the development of coping strategies with a changing climate.

Crops, animals and trees principally respond to succession of daily rainfall and temperature variations. Before climate change was actually detected, the use of long term climatic records allowed the determination of the probability of occurrence of a wide range of agroclimatic parameters of importance to agriculture and the risk associated with them. However, this period for use in response farming approaches has diminished to something as ten years under conditions of a changing climate. Therefore, agricultural management decisions are now better developed based on predicted seasonal rainfall. Some examples are provided in Table 4.6. Importantly, the consequences of these agricultural choices and the broader range of effects can be explored before any practical application. For these reasons, famers across the south-western Free State who participated in this relevant and necessary study on decision making were capacitated to make informed decisions endorsed by science based information and eliminating the dependency on guesswork and the use of traditional indicators.

Table 4.6 Some management decisions by farmers using seasonal rainfall predictions

Under predicted dry season (below normal rainfall)	Under predicted normal to wet season (normal to above normal rainfall)
1. Ensure land is cultivated timely prior to drier conditions	1. Ensure land is cultivated timely prior to onset of good rains
2. Order inputs (seedlings, seeds & fertilizer) prior to engaging in planting	2. Order inputs (seedlings, seeds & fertilizer) prior to engaging to planting
3. Concurrently check weather forecasts and climate predictions and draw an operational plan for the season	3. Concurrently check weather forecasts and climate predictions and draw an operational plan for the season
4. Minimize planting density by at least 25%-50% ha^{-1}	4. Introduce normal to higher planting density ha^{-1}
5. Minimize labour and other input use	5. Ensure there is sufficient labour and apply fertilizer
6. Plant just before the expected onset of the 1st rains	6. Adopt sequential planting and intercropping
7. Opt for drought tolerant crops such as sorghum & millet	7. Plant crop varieties (diversify)
8. Control weeds frequently	8. Control weeds more frequently
9. Introduce water conservation methods such as using different types of mulch	9. Strengthen the use of terraces and ridges/dykes to reduce erosion & surface run-off.
10. Minimize the area under cultivation	10. Enlarge area under cultivation
11. Apply (supplementary) irrigation where possible	11. Apply irrigation in the occurrences of long dry spells

During the duration of this study, it was notable through observations and informal interviews that farmers who were not familiar with the application of the agrometeorological information /advisories/services were prone to be mostly affected by climate shocks. These non-trained farmers were not exposed to early warning and other advisories, related or unrelated to weather forecasts and climate predictions, and therefore they were not prepared to mitigate/maneuver agricultural strategies. They had no coping strategies in place for risks reduction. Therefore, abundant room exists to expand and train extension agents on the nature of this study within the present and into other areas across the south western Free State.

4.5 Observations during the on-farm and study groups training

The goal of this subsection is to provide understanding and insights into pattern behavior and attitudes of farmers, during the introduction of weather forecasts/climate predictions and other science-based information for agricultural decision making during on-farm visits and study groups. Farmers felt a great need for learning on agrometeorological information/advisories/services for the uplifting of agricultural activities and the status of the farm. Importantly, farmers expressed an enormous interest in learning more about decision making and scenario selection with given weather and climatic conditions. The presence of the researcher as an agrometeorologist brought much hope to farmers to achieve improved agricultural production while minimizing unnecessary expenditure. This collaboration of farmers, extension agents and scientists brought assistance to farmers in order to be prepared for all type of predicted seasonal conditions. The environment in all study groups after rapport was built was very much conducive for interaction and exchange of information. The farmers were actively involved and participated on a monthly basis. In circumstances where participation was not possible, a representative was sent to study groups to learn about agrometeorological learning. On arranged on-farm visits, farmers ensured their availability as arranged. This was therefore an indication that farmers had learned to solve some of their agricultural problems and enthusiastically demonstrated undoubtedly the importance of agrometeorological information/advisories/services for their agricultural decision making.

As new concepts of information and new knowledge are introduced to farmers, it is required to understand their behavior. According to Măruşter et al., (2008), the decision making process is characterized by various iteration processes that seek to explore a range of issues in which additional information is developed and generated for new or other alternatives. It is, therefore, during this process when famers used weather forecasts and climate predictions, that they must weigh different options and scenarios for a given seasonal forecast, to generate information and new ideas on making suitable choices. The process of improved decision making is empowering and it is a learning phase on its own. It ultimately enables farmers to be independent thinkers. The ability to use science-based information increases as they learn and explore different scenarios (Fig 4.1). Following this mapping, outputs from decision support systems endorse the decision making process from information interpretation to the development of a range of scenarios based on the application of agrometeorological information/advisories/services.

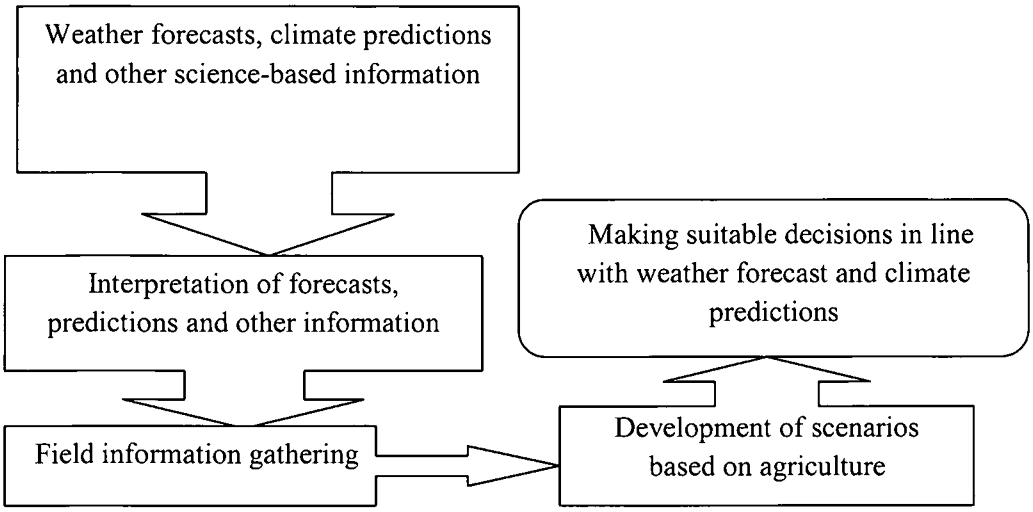

Fig. 4.1 Mapping the common decision making process for the application of (in our case) agrometeorological information/advisories/services

In general, most farmers who participated in meetings and workshops appreciated the value and the standard of information presented to support decision making. Interestingly, in the last season of the project, 2011/12, a form of the concept of Climate Field School (CFS) was adopted from Stigter & Winarto (2011). The participation in this kind of CFS was enormous and courageous since farmers had realized the importance and value of agrometeorological learning. Farmers demonstrated a great hunger and enthusiasm to learn more about the application of agrometeorological information/advisories/services. This is also being demonstrated by continuous requests of agrometeorological information and advisories in the post-project final phase.

The CFS accomplished across the study area entailed an advanced training on agrometeorological learning. This learning encompassed climate data collection, calibration of climatic sensors, monitoring and analyzing as well as application of climatic data based information/advisories/services to daily agricultural activities. During this process farmers participated and assisted in installing of automatic weather station and wrote a test on the use of the weather station. This exercise was inspired by the need to educate farmers as participating observers and with the aim to minimize vandalism of automatic weather stations

(AWSs) in the area. Therefore, through this training farmers developed a sense of ownership of AWSs since they knew they are the end user of the data. These AWSs were installed in the premises of farmers that were actively involved in agricultural production and were placed at distance of 50 km to 100 km from each other. The CFS curricula were developed according to the needs, vulnerabilities and challenges that applied to these farmers. Therefore, the training went according to plan since the intermediary was a well-trained agrometeorologist in collaboration with people from other disciplines such as animal health scientists, agronomists, forest meteorologists, horticulturalists, pastoralists and agricultural economists as required by the difficulties encountered by the farmers.

Agrometeorological information, advisories and services should not only focus on weather and its impact on agricultural production. The great requirement is one for an integrated approach to address the entire range of challenges encountered by the farmers wherever necessary. In a first example, Mr. Thebeagae from Soutpan is practicing mixed farming agriculture. Therefore, an advisory which only covers a particular agricultural enterprise should not be sufficient for him. Comprehensive tailor-made advisories should be useful, meaningful and purposeful. Such advisories should entail recommendations on problems relating to, pigs, sheep, goats, cattle, sunflower and maize production. But Mr. Mahlangu, from Ladybrand, would only be interested in maize production, while Mr. Khume from Thaba Nchu would only be interested in the production of *Eragrostis curvula* (see Appendix 1.12) for bale making and Brahman cattle production. These examples illustrate diversification in the challenges experienced by the farmers and a requirement for tailor-made advisories. Since local agricultural development requires area specific historical climate data (e.g. Gommes et al., 2010), expansion of AWSs across the south-western Free State and South Africa at large might be considered obligatory. Interestingly, farmers have noted and admired the use of agrometeorological information/advisories/services across the spectrum of operation.

4.6 Diverse decisions by farmers for different seasons

Farmers across the south-western Free State operate under diverse environmental conditions. They are challenged by different effects of unfavorable climatic conditions. Therefore, the iterative process of reviewing decisions made prior to implementation becomes the most central part of good decision making. With appropriate training, it should do so concurrently with the use of an action learning cycle for the reflection of decisions taken for improvement of agricultural decision making. The action learning cycle is adapted from the action research methodology used in qualitative research. It is a systematic cyclical method of planning, taking action, observing and reflection (Checkland and Holwell, 1998; Burns, 2007; O'Brien, 2001; Smith, 2006) for a group- and self-evaluation and critical reflecting prior to planning the next cycle for decisions in agricultural production (McNiff, 2002; Dick, 2002; Bessette, 2004; Reason and Bradbury, 2001; Tracy, 2007; Selener, 1997; Braun and Hocde, 1998, Whyte, 1989). The action learning cycle is aimed at addressing and identifying problems relating to agricultural strategies (Smith, 2006). It may ultimately improve the efficiency of using weather forecasts and climate predictions for the development of more detailed and more meaningful tailor made science-based agrometeorological advisories and be used as a tool to investigate and facilitate new information advancements (Seymour-Rolls and Hughes, 2000, Vernooy, 2003; Stigter, 2006; Stringer, 2007).

Action learning cycles involve direct participation of information developers (here for example the weather forecasters and climate predictors or those who develop seasonal outlooks from climate predictions, as well as establishers of other agrometeorological services in farmers' fields), intermediaries and end-users in a dynamic research process. Applying an action learning cycle allows the users of information/advisories/services to more thoroughly develop agricultural scenarios given the weather and climate conditions for diverse environments. Ideally, the reciprocity of information exchange amongst information suppliers, information disseminators and information users (Wadsworth, 1998; Reason and Bradburyn, 2001; Carr and Kemmis, 1986) may benefit all involved in the supply chain of knowledge for decision making in agricultural production.

The introduction of agrometeorological information/advisories/services began in a few towns such as Sannaspos, Soutpan, Brandfort, Koffiefontein, Verkeerdevlei and Jaggersfontein in 2008 and expanded to Thaba Nchu, Botshabelo, Tromsburg and Ladybrand. The attitude of the farmers changed and they realized the importance of the application of agrometeorological knowledge for sustainable and successful agriculture. The project was conducted for four seasons from 2008/09, 2009/10, 2010/11 and 2011/12. Interestingly, farmers continued patiently and participated in workshops as they learnt and apprehended the use of weather forecasts and climate predictions. The impact of the application of weather forecasts and climate predictions and other science-based information became more visible in the 3rd and 4th planting season (2010/11 and 2011/12). During these last two seasons farmers were more established and confident to incorporate the agrometeorological knowledge, while the services were available. Farmers realized the necessity of interpreting (scenarios from) weather forecasts and climate predictions for their conditions since they have lived the reality of the climatic shocks and other unreliable climatic conditions.

We give an example on how the action learning cycle was preliminarily utilized to enforce the continuing development of decision making and the further adaptation of the use of agrometeorological knowledge. Farmers adopted this concept of an action learning cycle which emphasizes on planning, acting, observing and reflection.

Planning – the planning phase was conducted under the umbrella of Design and Planning stage 2 of the Farming Systems Approach (FSA). On monthly meetings the weather forecasting/climate prediction information from different stakeholders such as the Agricultural Research Council (ARC), University of the Free State (UFS), Council for Science and Industrial Research (CSIR) and South African Weather Services (SAWS) contributed science-based information, which was incorporated in the presentations and advisories for the participants. For example, a frost chart was used to select frost free days for the summer planting season; as earlier discussed the 2008/09 seasonal forecast predicted above-normal rains for January-February-March (JFM). This information was a guideline to farmers and the plans taken were late planting (last week of December and first week of January), increasing of planting density, investing in more land cultivated and buying of fertilizers, opting for short maturing maize cultivar, preparations to control weeds and pests. Vegetable farmers emphasized crop diversification and intercropping was a popular option.

Acting – This is the implementation of the plans taken by the farmers as guided by weather forecasts and climate predictions. The implementation of the actions occurred on farms and followed the work plans drafted during workshops and meetings. The implementation of these plans depended on the capitals available on the farms. Most of the resource poor farmers were farmers with excellent plans that were not executed timely as a result of lack of labour, enough operational implements and other goods depending on capital. Through the commitment of extension agents in our meetings some of the challenges were met. Farm work plans entailed suitable management practices guided by agrometeorological advisories and were all farmer differentiated.

Observing – observations of executed plans were made continuously throughout the growing season and at all crop growth stages, different tree stages and following animal developments. Farm visits were conducted and pictures were taken as part of teaching aids in all farms to educate other farmers on what was actually happening on the farms of the participants. Provision of information/advisories/services continued, including daily, weekly, 14-days (Figure 4.2) and monthly (Figure 4.3) rainfall forecasts/predictions. In circumstances where crop damages were noticed, such as with the infestation of diseases or the outbreak of pests, agronomists were available to advise on pesticides and insecticides to be used. In some instances, drying of crops in too long dry spells resulted in poor crop production since there were no means of supplementary irrigation. Hence, famers who selected drought tolerant varieties benefited from just making a suitably cautious decision for the predicted above normal seasonal rainfall forecast. This was largely more a matter of luck than of understanding as rainfall distribution is not part of the rainfall forecast.

Reflecting – Therefore, the reflection phase of the project was the reviewing of the results of the decisions implemented under the given seasonal predictions. These seasonal predictions were given to the farmers for both, summer and winter seasons, since in the study area some farmers are involved in winter grain and vegetable production (for example winter wheat, onion and cabbage). Post-harvesting, farmers were given the opportunity to share their experiences from throughout the season for the future amendment of the plans previously made. Most farmers continually developed interest in participating in agrometeorological meetings and workshops. This is also witnessed by seeing new members in workshops and invitations to train extension agents. Therefore, the action learning cycle in its seasonal form was used constantly while engaging farmers. Farmers understood from their experience that should January, February and March be predicted as with above-normal rainfall, it is critical for farmers to do preparations late in the season and not as usually in October, November December. Such a decision on early planting may have a devastating turnout and result in different grain yields, since late planting would give higher yields than to farmers who decided to plant by early October, November, December.

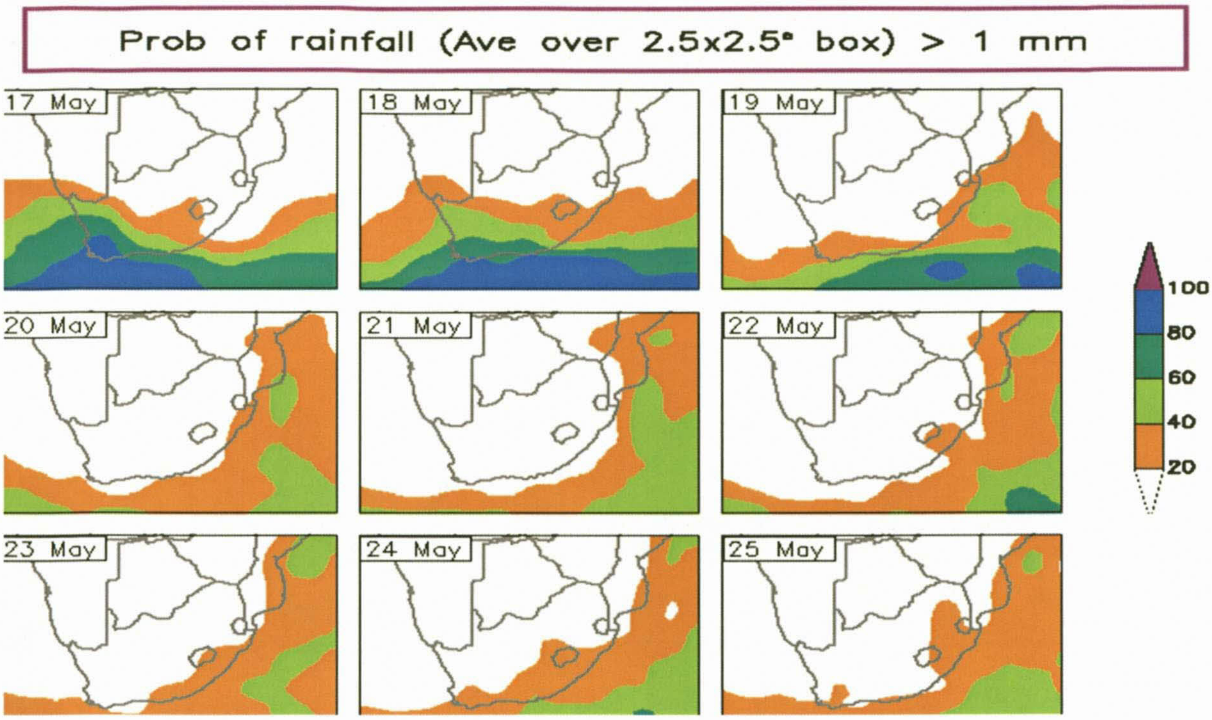

Fig. 4.2 A 14 day rainfall prediction issued 11 May (http://www.weathersa.co.za)

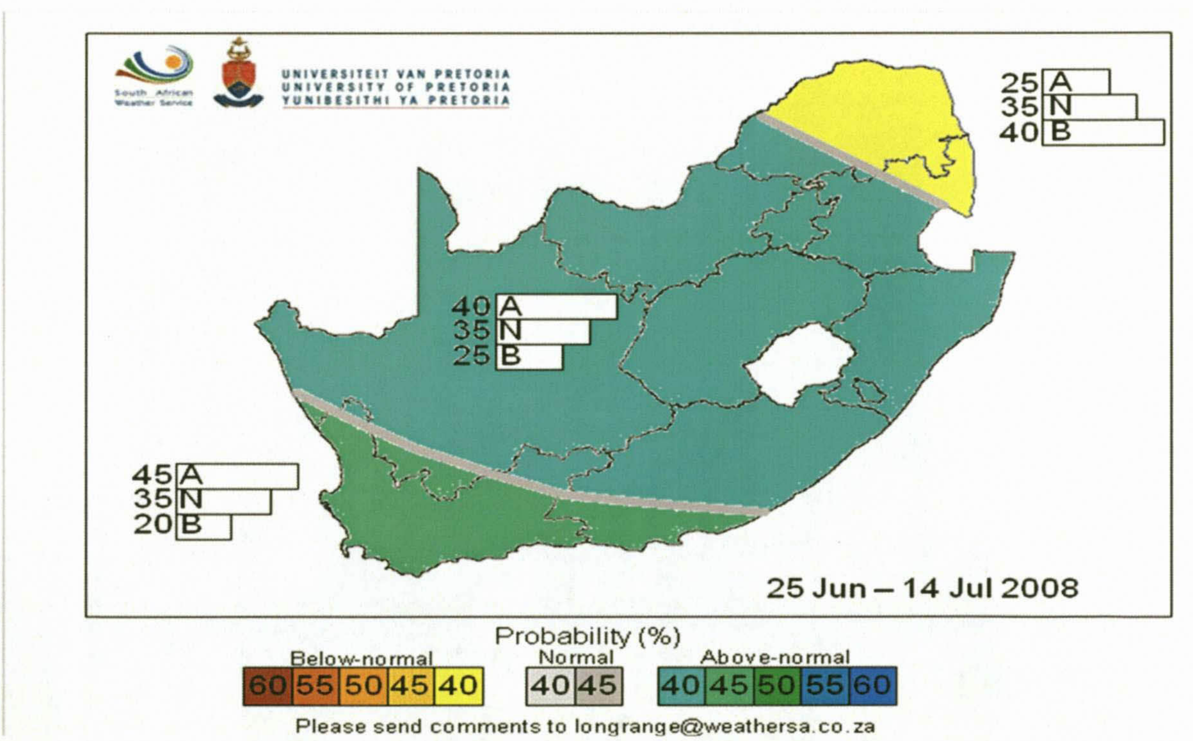

Fig. 4.3 Monthly rainfall predictions issued (http://www.weathersa.co.za)

A report from farmers in Sannaspos indicated that agrometeorological information (in this case a daily forecast) is a pillar towards proper on-farm planning and sustainable agriculture. Since Swiss chard producers in the area had planned to harvest the Swiss chard on 12 July 2008, the activities as planned contradicted with the forecasted rainfall conditions, since good chances of rainfall were predicted for that particular day. They therefore instructed laborers to harvest on 11 July, the day before the rains forecasted. Such a decision has a great impact on reduction of risks and efficient use of farm laborers.

On a prediction of 20% chances of rains occurring in the next 7 and a prediction of less than 5 mm in the 14 days, farmers suggested to prepare tractors. Should good rains be received, the land must be ploughed to kill weeds and allow the water to infiltrate into the soil. Poultry farmers introduced heaters when prediction of minimum temperature was low and cold conditions could result in broilers fatality. Whereas Soutpan farmers experienced huge losses on fruit trees stricken by a black frost incidence, which occurred during the flowering stage. Therefore, availability of relevant agrometeorological information/advisories/services should be made possible to all farmers for the development of profound tactical and strategically planning with a distinction of tailor-made advisories rather than generalized knowledge.

4.7 Impact assessment

Following the positive decisions on the proposed and conducted study in the south-western Free State, a gap in availability of supporting knowledge for agricultural decision making was identified. Workshops were launched to have this element addressed by the information developers and those funding the project. In the end we wanted information on the ultimate impact assessment regarding this knowledge as a whole. This impact assessment was prepared to explain the requirements that arise from interactions and activities undertaken with the communities. It would be beneficial, therefore, to clarify the aim of impact assessment with regard to the objectives of such a study. The impact assessment in this case was used to particularly identify and assess the impact relating to weather forecasts and climate predictions and the application of other science-based information on the objectives pursued (Jones, 2001; Agarwal, and Mall, 2002). Impact assessment was used regarding achieving the proposed project objectives and could eventually, in the final analysis, be applied to the impact on livelihoods of the farmers and their economic status.

Impact assessment outlines the advantages and disadvantages of choices made and investigates possible synergies for the development of suitable interventions that seek to reduce agricultural disasters. Impact assessment in this regard took place during the development of agricultural decisions based on the iterative steps of an action learning cycle. It may occur prior to the endorsement of a proposed or suggested intervention, or when the proposed intervention has been approved or it may occur in between these two stages of information generation. The impact assessment was conducted at the stages of FSA starting from design and planning stage of the project in which an action learning cycle was used as a complementary tool to interact with the farmers and exchange understanding. At the project description stage, an action learning cycle was not feasible since the objective of this stage was to identify and assess agricultural enterprises, the availability of agrometeorological information, advisories and services to farmers and the existing channels of information dissemination.

Agrometeorological knowledge impact assessment has two characteristics, which are the internal monitoring of continuous learning, in for example the exposure to the usage of weather forecasts, climate predictions and other science based-information. Farmers at all levels were introduced to different types of forecasts and were guided on their interpretation and application in agricultural decision making. Farmers were introduced into existing information management systems from different stakeholders responsible for the provision of agrometeorological information/advisories/services. The internal ongoing learning was interlinked to the second characteristic, the external impact assessment, and the latter involved the development of interventions which were related to the use of weather and climate knowledge. Preparedness through early warning systems was one important factor to counteract climatic shocks. For examples, early warning advisories encouraging farmers to be prepared for weather events such as heavy rains, hailstorm, snow, strong winds or may be the likelihood of fires to occur. Provision of such warnings allowed farmers to take possible interventions to minimize risk occurrences on crop/animal and agroforestry.

Impact assessment commenced during the design and planning phase of the project into the implementation phase and, lastly, covered the results of the dissemination of developed tailor -made advisories (Figure 4.4). During these project phases a wide range of methodologies was used to generate advisories such as quantitative statistical methods, qualitative methods and participatory approaches (see methodologies Appendix 1B). The quantitative statistical methods were utilized during the baseline study to identify the livelihoods of farmers and their economic status, in order to assess the consequences of the application of different types of suggested interventions (Table 4.4). Concurrently, while interacting with the farmers qualitative methods were introduced to scrutinize the farmer's livelihoods, farming systems, application and availability of weather forecasts and climate predictions as well as other science-based information (see Chapter 3). In most cases impact assessment was finally conducted through the observations of the change in farmer's behavior (see Chapter 2) and the final agricultural product. It is also worthwhile to indicate that as part of impact assessment of course participatory tools were intensively used to interact with the farmers from baseline study to development of interventions to implementation of decision choices from advisories (see also above).

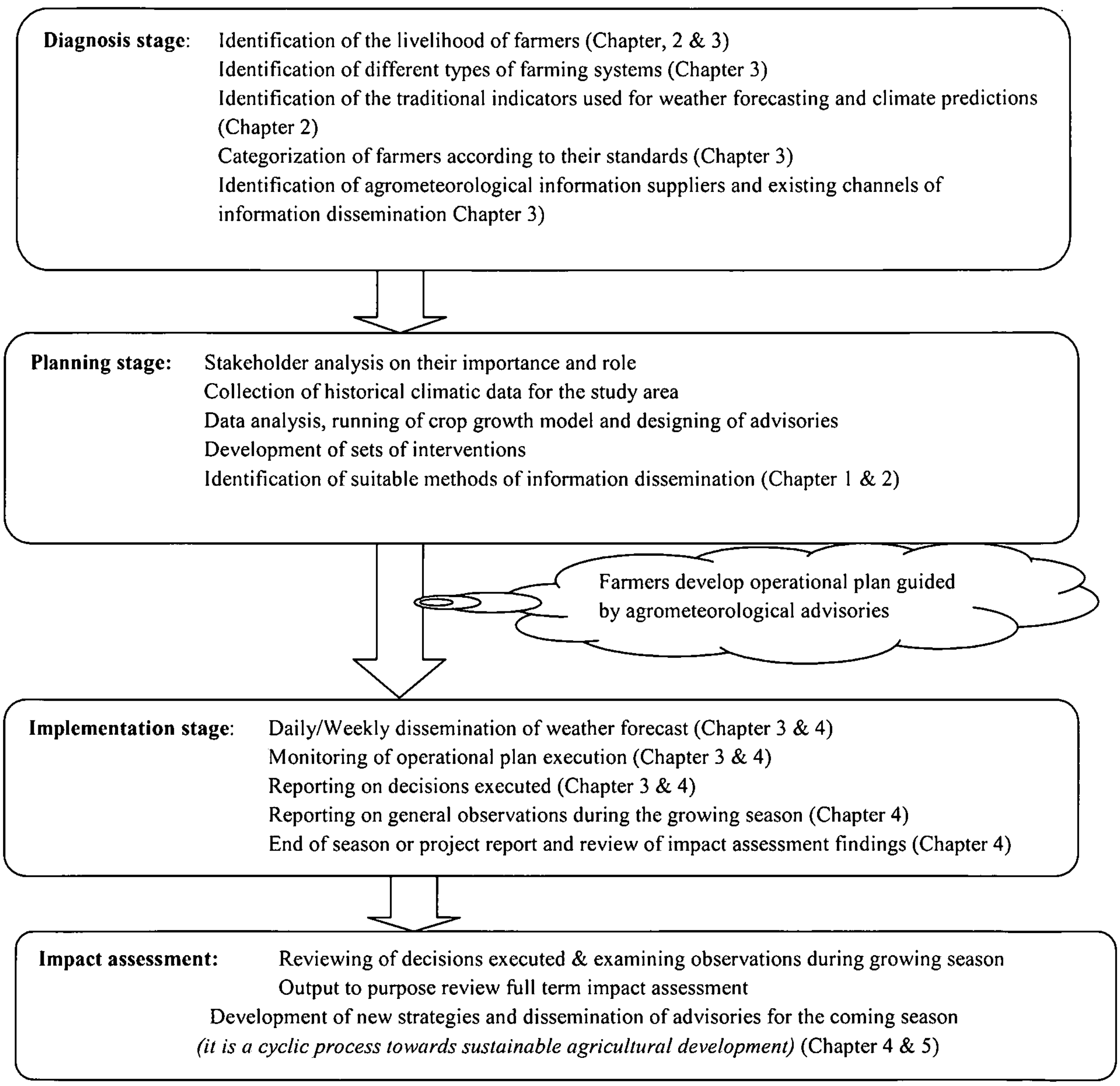

Fig. 4.4 Critical stages for impact assessment for the application of agrometeorological knowledge.

Eventually, impact assessment is possible through the use of a mix of techniques with the involvement of key stakeholders and the reliability of agrometeorological advisories which are accurate and timely disseminated to the users which are the farmers in this case (Chapter 3). This study was an attempt to improve the status of agrometeorological knowledge whilst seeing to improve agricultural status with the application of agrometeorological information/advisories/services. The results or findings from the previous season were prioritized risk assessment to identify farmer's vulnerabilities and this basically was used as a starting point for the development of new interventions to alleviate the agricultural damages. For example, farmers who planted too early or later then it was recommended had to change planting dates according to the weather forecasts and climate predictions. Crop production, animal production and agroforestry is sensitive to weather and climate, hence agrometeorological products can assist farmers to develop suitable coping strategies.

Chapter 5

An Extension Approach to Close the Gap Between Suppliers and Users of Agrometeorological Information/Advisories/Services in the South-Western Free State

5.1 The existing gap between developers and users of agrometeorological information/advisories/services

Plants, animals and trees undergo life cycle changes as they encounter dissimilar weather conditions and are subjected to biotic and abiotic stresses (Davitt, et al., 2011; Wahl, et al., 2011). As we saw in previous chapters, the most troublesome abiotic stressors occurring in the study area that are related to climate are storm winds, extreme temperatures, drought, floods, hailstorm and wildfires, while biotic stressors include the living disturbances such as detrimental insects to agricultural production (Kanninena, et al., 2013). After the development of sufficient and relevant agrometeorological information/advisories/services to counter those disasters and their consequences, training of extension intermediaries or extension agents/officers remains the most crucial part of information/advisories transfer and services establishment in farmers' fields (Weiss, et al., 2000; Stigter, 2010; Winarto & Stigter, 2011).

The implementation of this study made major changes in the availability of and farmer's perceptions on agrometeorological information/advisories/services as well as the channels and methods of dissemination. Across the study area the use of Internet was only limited to a few commercial farmers. This is not just the case in the south-western Free State but it is true across the African continent. Currently, the most effective method of information dissemination differs from farmer to farmer and is predetermined by the farmer's capabilities; resource poor farmers in the study area mostly utilized the study groups and short message services. However, information/advisories and, where people can assist to establish them, services, can be disseminated by sending them to key communication outlets that are readily used by most people such as television, freely available local newspapers, local radio, bulletins, ward committees, extension forums and early warning committees. The agrometeorological details should entail relevant and tailor-made information/advisories/services that are directly useful to the farmers and the latter should be able to interact with the sources. For farmers in the south-western Free State to embrace the use of agrometeorological information/advisories/services would ideally require the interaction with extension agents to obtain the necessary knowledge.

As already earlier indicated, from extension training and workshops held in the south-western Free State, it was discovered through questionnaires that most extension agents (Appendices

1.9 and 1.10) in this area had no basic knowledge/understanding/training in agrometeorology and its applications to agriculture. Several gaps that were considered to hinder the process of information/advisories/services flow from suppliers to users were:

- ✓ Lack of basic training on weather and climate knowledge and understanding
- ✓ Lack of training on basic operational agrometeorology
- ✓ Lack of communication between suppliers and users
- ✓ Lack of agrometeorological advisories/services available to farmers
- ✓ Lack of skills to interpret weather forecasts and climate predictions for agriculture
- ✓ Lack of information on the potential suppliers of agrometeorological information/advisories/services
- ✓ No clear channels of information etc. dissemination
- ✓ Advisories available are too general, not understandable and not point specific
- ✓ No feedback from users to suppliers of agrometeorological information/advisories
- ✓ No availability of agrometeorological services
- ✓ Poor rainfall recording on farms

Therefore, training of extension agents in this study area became a priority since they are potentially the key people to close the gap between suppliers and users of agrometeorological knowledge and understanding contributing towards sustainable agricultural development. Extension agents were involved in and facilitated the process of communicating agrometeorological information/advisories and assisting farmers in the development of decision-making for tactical and strategic operations and they ensured that the decisions were correctly executed. This means that training of trainers becomes the most important factor towards successful farming and to ensure that farmers get more self-reliant and independent.

The purpose of this chapter is to explore different approaches for the establishments of an extension agrometeorology (Stigter and Winarto, 2012) across the south-western Free State, in which suitable intermediaries become well skilled to particularly articulate the needs of the farmers and of the farming community at large for agrometeorological information, advisories and services. The topics of interest that needed attention in the south-western Free State were in operational agrometeorology regarding agrometeorological services in relation to crop management, crop protection, monitoring and early warnings of natural disasters, and preparedness for other risks in weather and climate, making use of weather forecasts, climate predictions and other science-based information for agriculture.

5.2 Agricultural extension response to agrometeorological learning

During the diagnosis stage of the project, extension officers were the key agents to access the farmers. They were familiar with practiced agricultural enterprises, challenges faced by the farmers and environmental conditions in the region of operation. The local study groups were identified with the assistance of the extension agents of the region, except for two study groups in Koffiefontein and Jagersfontein, where the local Municipality representative played a major role in organizing farmers and workshops, while afterwards the study group leaders took over. The extension agent training workshops were organized for two occurrences in October 2009 and the last training took place in April 2012 and was held at the University of the Free State.

During the extension agent training in 2009, a group of animal nutritionists, animal health specialists, crop scientists, pasture & veld scientists and extension officers participated in the agrometeorological extension training. The topics dealt with during the training were, among others, the interpretation of short-, medium- and long-range weather forecasts and climate predictions for agricultural purposes, crop type suitability, selection of crop cultivars, calculations of degree days (thermal time) for maize cultivar selection, maintenance and calibration of automatic weather stations. The institutions and organizations that were responsible for the development of agrometeorological advisories were listed to ensure that information suppliers were well known (Chapter 3). The training focused on agrometeorological knowledge, concepts, principles and their application to agriculture training. Questionnaires were given to the extension officers prior to and after the training workshop to assess their level of agrometeorological understanding and to subsequently evaluate the training (see also Appendix 1.15).

The first training that took place was for a group of 30 extension agents in October 2009. In April 2012 19 extension agents were trained. These training workshops were structured in a very participative way. Under the main theme of operational agrometeorology, the crux of these workshops was based on the emerging practices in participatory poverty reduction and establishment of food security. Active agricultural enterprises and choices in different regions were discussed such as small and large stock production, vegetable production, grain and sunflower production. These were entry points in identifying the needs relating to weather and climatic conditions. This training of trainers workshop was organized by the Agricultural Research Council's Institute for Soil Climate and Water (ARC-ISCW) and the University of the Free State (UFS), who were also the organizers of the research study on which this thesis was written. The questionnaires were structured in a manner to evaluate extension agent's perceptions on weather forecasting and climate predictions and their understanding of and experience in agrometeorology as well as to discover whether they could make this accessible for guidance of daily agricultural activities. We also jointly identified suppliers of agrometeorological information/advisories/services and the existing channels of their dissemination from an extension perspective. The results of the analysis of the replies to the 2009 workshop questionnaires were very unbalanced. The findings indicated that agrometeorological concepts needed to be incorporated in their agricultural training. The detailed results were as follows:

- ✓ 13% of the extension agents indicated that they had a good background and understanding of weather forecasting and climate prediction information and their application to agriculture, whereas 87% expressed to have very little knowledge on these subjects;
- ✓ 20% of the extension agents did not often listen to weather forecasts nor did they receive climate predictions, while 80% listened to SABC for daily weather forecasts and read climate information from the daily newspaper;
- ✓ 56% of the extension agents did not personally receive directly any types of weather forecasts, 36% did receive rainfall and temperature forecasts that way and only 6% received all types of forecast personally;
- ✓ 86% of the extension agents did actually not understand the differences between short, seasonal and long-term forecasts and 14% had a clear understanding of the usage of this terminology;
- ✓ 16% of the extension agents indicated that their farmers did receive the weather forecast and climate predictions, but 84% said their farmers did not receive any type of weather forecasts or climate predictions;
- ✓ 97% indicated that their farmers should have access to agrometeorological information for decision making support towards improved agricultural productivity;
- ✓ 70% of the extension agents had doubts on the reliability of weather forecasts and thought that the products were not user friendly;
- ✓ Although 27% of the extension agents mentioned that they could interpret the weather forecasts at their disposal, 93% requested thorough one-week training on agrometeorological information/advisories/services, as they are the backbone of their daily activities.

The questionnaire analysis for the extension agent workshop held in April 2012 had the replies of 19 participants while 11 expected participants did not arrive as a result of an unforeseen traffic accident blocking the only road. The participants consisted of 13 male and 6 female employees with their age ranging from 26 to 48. The field of operation amongst these participants slightly varied from extension agent (16), food security officer (1) to agricultural advisor (2). These participants had good qualifications since some obtained Bachelor Degrees in Agriculture, Bachelor Technical Degrees in Agricultural Management, Diplomas in Agriculture, National Diplomas in Animal Production and Masters in Technical Agricultural Management but qualification does not make them good extension agents per se, but experience is most required. These participants were each responsible for groups of farmers ranging from a minimum of 20 farmers to a maximum of 400 farmers per extension agent. These farmers owned land from 1ha to 3000ha. The results from the analysis of the questionnaires of the workshop conducted in 2012 indicated the following:

- ✓ 79% confirmed the receipt of advisories through e-mail from ADRIM but did not use them and 16% indicated that they did not receive them at all
- ✓ The suppliers of information mentioned were ADRM, SABC, e-TV and the ARC which provided presentations and pamphlets during study groups
- ✓ E-mail was rated the most preferred method of information dissemination
- ✓ 11% of the participants indicated that they received traditional forecasts and predictions from farmers and 89% had no access to this kind of information
- ✓ 58% of the participants confirmed to use the weather forecasts and climate predictions to organize information days and advise farmers
- ✓ 68% of participants indicated that they did not make use of traditional weather forecasting and climate predictions but 32% mentioned that they made use of such information and that the information.(see also Chapter 2).
- ✓ 37% of participants pointed out that they are capacitated to interpret weather forecasts and climate predictions and other agrometeorological advisories but 63% indicated to have no experience at all in the interpretation of advisories
- ✓ All participants were concerned about the value of seasonal climate predictions since they indicated that it was unreliable and in their eyes valueless
- ✓ Participants thought that with intensive training on the application of science-based information and the interpretation of advisories they could be easily used

- ✓ 90% of participants had good understanding of the meaning and the interpretation of normal, below normal and above normal rainfall in climate predictions while only 10% had no ideas on it
- ✓ 79% of participants were able to explain the use of probabilities and make suitable recommendations from them but the others could not
- ✓ participants were in the position to develop recommendations for their farmers based on drought predictions and the examples provided were to minimize planting density, to plant drought tolerant crops, to reduce stock, to be in need to have food and/or fodder banks, to consider water conservation techniques, to allocate grazing camps accordingly and to buy supplementary feed/fodder, to plant under irrigation where possible
- ✓ participants did neither make efforts to obtain climate predictions and other science-based information nor efforts to obtain traditional climate predictions
- ✓ most of the participants felt the importance of paying for the forecasts but thought that the exercise would be unnecessary and suggested that the DAFF could pay for agrometeorological advisories.

According to participants from both training workshops they received the National Agro-meteorological Committee (NAC) advisories (See Chapter 2). The weather forecasters such as the South African Weather Services (SAWS), ARC-ISCW and other centers are also responsible for the development of the seasonal outlook. This information is sent to the National DAFF, where suggested agricultural activities from the farmers, through the extension agents, are incorporated into the seasonal outlook to develop a NAC advisory. This advisory is transferred back to the provincial DAFF to be sent to ADRM, the unit that deals with agricultural risks and disasters. This NAC advisory goes through to the EWC that is the body of expertise from different disciplines in which extension agents are represented, for cross-examination and double checking on its relevancy for the coming season. With the amendments and the approval of the EWC, the NAC advisory is forwarded through e-mails to the extension agents. They eventually have to reach the farmers to be used as the support tools for on-farm decision making (Fig. 5.1). The NAC advisory guideline is too general and is not point specific, which makes it rather difficult for the extension agents to understand it and convey it to the farmers. This process provides no room for the feedback from the farmers to present their suggestions about the advisory. From our experience, we feel that the existing channels used for the NAC advisories and the manner they are developed need to be reviewed. In improved form it should address the specific recommendations for diverse groups of farmers and the extension agents should be able to discuss them with the farmers and get feedback.

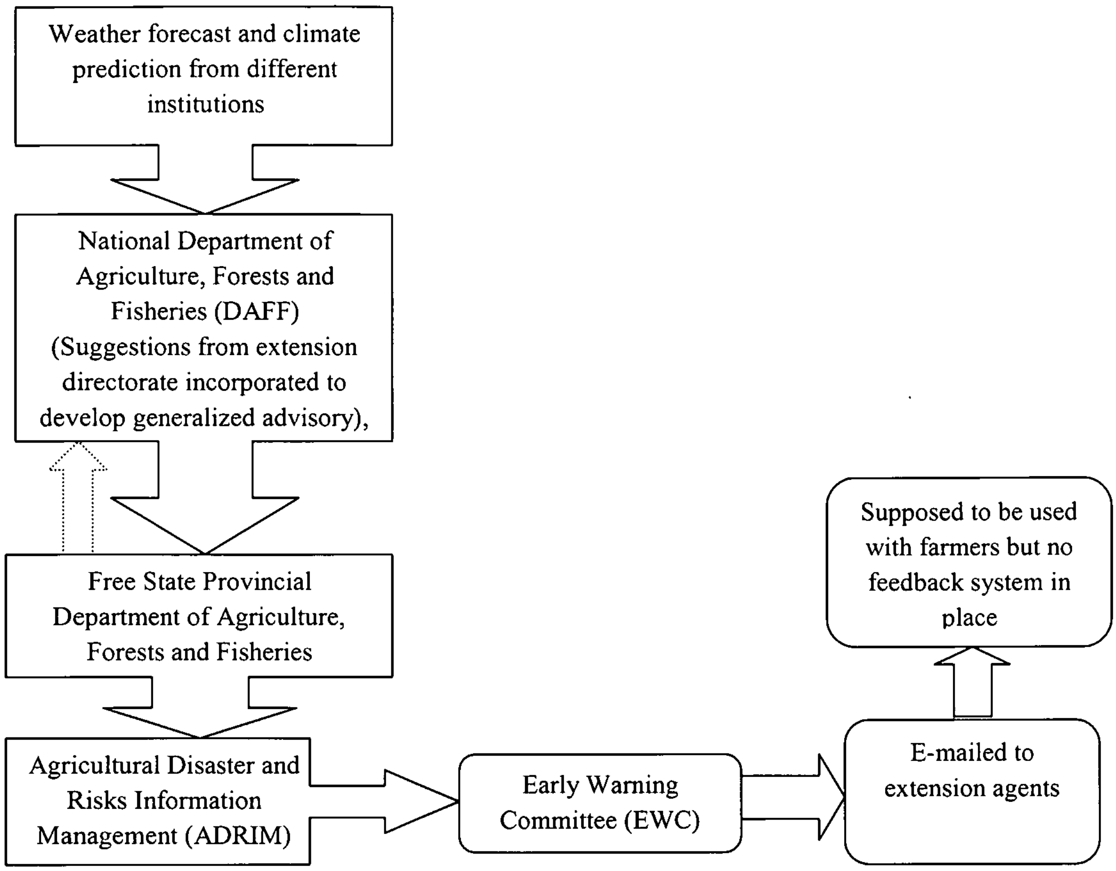

Fig. 5.1 Current flow and development of agrometeorological advisories in the Free State.

This study proposes from the above a strategy to develop and transfer agrometeorological advisories from the national DAFF as follows:

i. to appoint a group of weather forecasters using different Global Circulation Models and including predictions from other International Climate Prediction Organizations (NOAA, IRI, APCC)
ii. to request, where possible with sufficient skill and accuracy, downscaled climatic conditions per region at a high resolution
iii. to hire a qualified team of agrometeorologists to develop tailor-made advisories per region and where possible per farm (see also Gommes et al., 2010)
iv. information/advisories/services developers can interact with the extension agents to address the needs of the farmers at grass root level
v. development of tailor-made advisories which strengthen diverse farming methods and sustainable agricultural development

vi. to implement conducive strategies of information dissemination as preferred by and suitable for the farmers
vii. delegation of weather forecasters/climate predictors and agrometeorologists to train extension agents during their monthly regional Extension Forums
viii. ensure dissemination of client friendly agrometeorological information/advisories/ services from intermediaries to farmers
ix. strategize and develop a two-way communication from farmers to intermediaries so that farmers' concerns can be sent back to advisories/services developers
x. a two-way communication to give extension/feedback from farmer to farmer may positively influence the degree of application of agrometeorological information/advisories/services (as illustrated in Figure 5.2).

The better way of information dissemination that was discovered during the period of this study was the participation of intermediaries in the organized study groups per area. This platform encourages the interrogation and discussion of advisories for better clarity and good planning. The proposed strategy ensures open discussion and transparency from stages of information/advisories/services development to training of intermediaries and to the application of the ultimate results by the end-users. This strategy shall allow users from different levels of farming to be able to consider the relevance of agrometeorological information/advisories/services towards successful agricultural development. Ignoring the two-way communication may result in uncertainties and unnecessary information distortion. But with the provision of an open end situation, smooth flow and understanding of information/advisories/services may have outstanding results.

Comparing the results from both groups at the 2009 and 2012 workshops, we can conclude that the participants were satisfied about the information packages for the workshops but had additional comments as in Box 5.1. The agrometeorological information is very relevant to the changing climatic conditions which are dominated by more and more severe extreme meteorological and climatic events. The proposition was the intensification of Agrometeorological days across the districts. The advisories were for the benefit of the intermediaries and the end-users since the research study ended. The participants found the prepared information presented also marvelous as to its usefulness towards contributing to food security and generation of money.

Advocacy in the implementation and expansion of the application of agrometeorological information/advisories/services should be possible by the support from the provincial ministry of Agriculture and Rural Development. This research study on extension agrometeorology focused on the Modder/Riet catchment in the south-western Free State. Advocacy is only possible through the study partners' networks and the study anticipated contributing to developing a replicable model of study groups for sustainable agricultural productivity. With study groups in all identified towns of the study area, during the meetings the intermediaries and the farmers were empowered to be able to develop their own local weather and climate coping strategies.

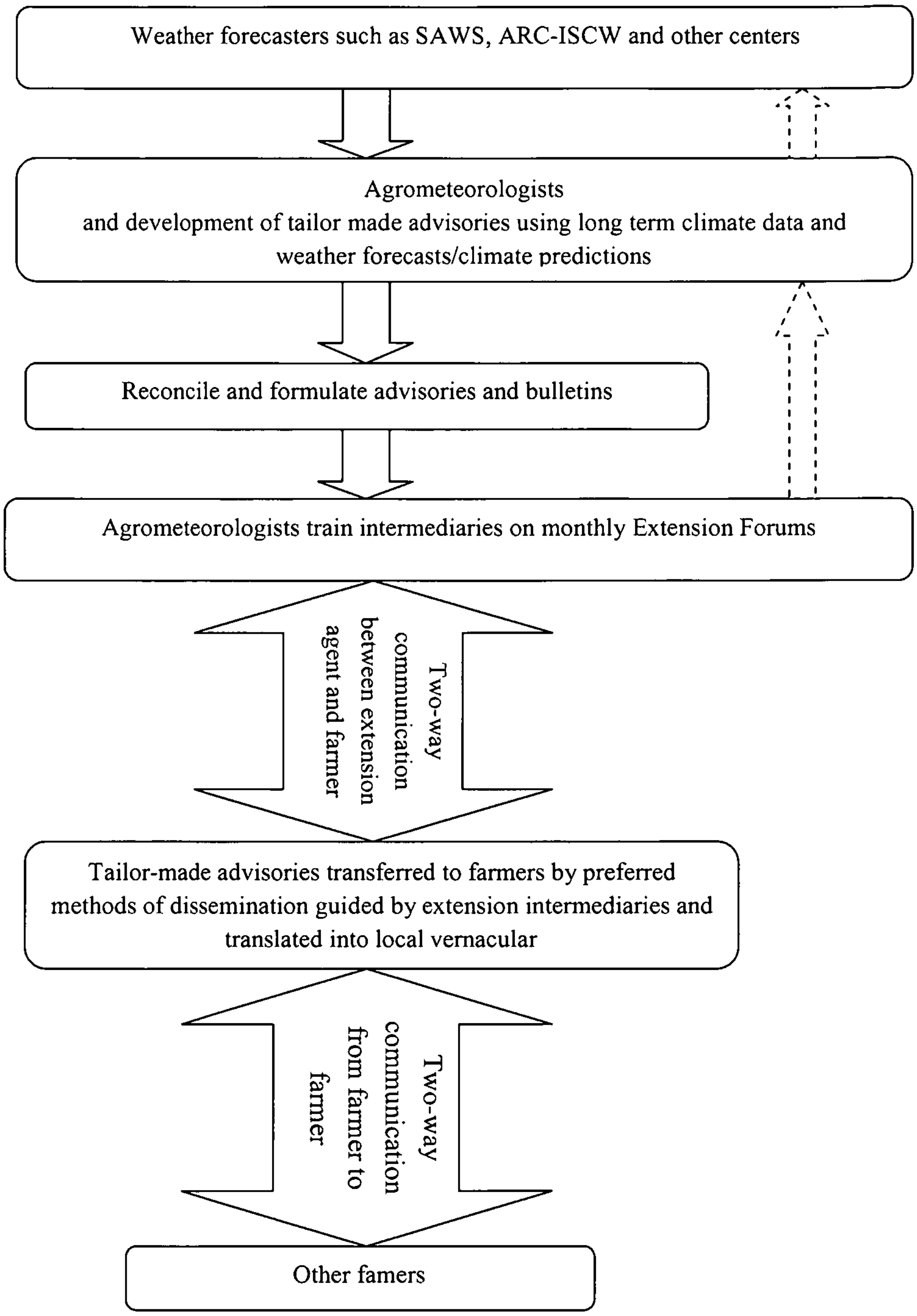

Fig. 5.2 Proposed strategies for agrometeorological information/advisories/services development, transfer and sharing.

Box 5.1 Additional comment notes from participant

The information presented in agrometeorological information workshops was an eye opener, but it was too much information for one day, a request for one week training is made.

More information days on agrometeorological information should be arranged and organized for all districts and presentations should give specific examples that focus on the districts.

The workshops were very informative but need to be conducted more often. It should have more details on local innovation and farmer knowledge, specify methods of information transfer. This information should be presented to Agriculture and Rural Development Management.

The training lacked practical examples for local experiences. There is a need for intensive training for crop and livestock production.

Agrometeorology should be included as a course in the extension curriculum at technical colleges and universities.

Agrometeorological advisories must be sent a month prior to the planting season for proper planning on agricultural activities and recommendations made must be realistic and implementable by all types of farmers.

The contact person in request for weather forecasts and climate predictions must be given the list of extension agents in the districts, with their e-mails, to send the advisories as soon as they are available.

5.3 Farmers response to agrometeorological learning

The work of the researcher was to assess and evaluate the availability and the application of agrometeorological information/advisories/services in the study area. The farmers were monitored and evaluated from the inception of the project till the end of the project. To determine the performance, production as to the final yield or outcome was used as an indicator (see Chapter 4).

The farmers were exposed to weather forecasts, climate predictions and other science-based information. Agrometeorological advisories were developed and sent to the extension agents and through them to farmers. Exposure to such type of information was gradually adopted by the farmers and the extension agents. After the season 2011/12, prior to project termination, the final workshop was organized for all study groups to determine the experience of the farmers in agrometeorological learning. The guiding questions were prepared to probe for more information and ascertain the response from the farmers (Box 5.2). At this stage of the project the focus was on accumulating the response from farmers. This process was organized to allow farmers to raise their most sensitive views without being offensive. At this final stage, the researcher had built good rapport with the farmers of all study groups. During the final workshops farmers were divided into smaller groups of 3-5 participants per group.

These sub-groups were given 5 minutes to discuss and write down the answers. Thereafter each presenter was given a chance to state the experiences from the group. The researcher summarized the responses from all study groups across the south-western Free State.

Box 5.2 Guiding questions to enhance future participation and representation

- ✓ Who should be involved in the different stages of developing agrometeorological information? What are their roles and responsibilities?
- ✓ What kind of information should be incorporated in the advisories?
- ✓ What challenges and limitations are faced by the farmers prior to the season and within the season? How can these problems be resolved?
- ✓ What is the role of extension agents in the shaping of decisions undertaken on farm?
- ✓ Why farmers opted for the agricultural enterprises executed on farm?
- ✓ In cases where climate damages occur, what do you usually do to minimize the extent of damages?
- ✓ What will be your most preferred method of information dissemination?
- ✓ Do you share your skills learnt at workshops with other famers who were not part of study groups?

Box 5.3 Accommodating farmers from different backgrounds in study groups.
[Different groups in study groups were represented by the elderly, youth, women, men, resource poor farmers and commercial farmers.]

- ✓ Need to stay calm, focused and with good listening skills
- ✓ Remain sensitive and very patient
- ✓ Do not teach or appear to teach
- ✓ Be able to ask questions in local languages or organize for an interpreter should it be necessary
- ✓ Avoid appearing patronizing and try to be at the level of the participants
- ✓ Allow all participants to contribute
- ✓ Appreciate different contributions
- ✓ Plan everything with farmers in time and make sure the task at hand is well understood
- ✓ Where possible arrange different meetings for specific groups and attend to unique needs during on-farm visits
- ✓ Be attentive to behavior and level of participation
- ✓ Listen attentively to the stories of the farmers
- ✓ Ensure to address issues indicated by farmers at level best

During the process of facilitating this exercise, observation of the behavior of farmers and listening to arguments in groups were other tools used to combine the response from the farmers. The ideas considered during the ongoing process in order to accommodate different groups were listed (Box 5.3). Although not every single farmer could be heard, a participatory approach contributed to building agreement and collective learning. This assisted farmers to feel empowered in the process, which increased self-confidence in application of agrometeorological information/advisories/services and lead to substantial change. The focus was on exploring different farmers' stories and on-farm experiences. But at the beginning of the applications some farmers seemed not to be well equipped to handle and deal with new information and new challenges. But with proper monitoring and evaluation during on-farm visits, farmers developed confidence and determination towards adopting agrometeorological information/advisories/services and got away from their old ways of doing things. For example, the turn up at study group's workshops gradually increased and the enthusiasm to learn accumulated.

The study groups presented a very diverse situation in terms of experiences, challenges and needs that are related to their farming. The consequences of increasing climate variability needed greater emphasis as to farmer's ability to develop on-farm coping strategies and interventions. A successful farmer should understand the local trends in climate change and how agricultural outcomes are influenced. For example, the concept of response farming (e.g. Stigter, 2010) prepares the farmer to be aware of past and future climatic conditions and of the extent of increasing climate variability and related dangers and interventions to reduce vulnerabilities.

In my experience as a researcher and an intermediary for the past five years, climate monitoring, record keeping and improved preparedness were the most emphasized issues during in-field training. Climate monitoring was emphasized with the use of rain gauges to measure rainfall and keep daily records. Two automatic weather stations were installed in two Sannaspos farms, one towards Ladybrand and the other one in Petrusburg. Record keeping played another new role for farmers to record all activities implemented on-farm against time (compare Winarto and Stigter, 2011). This allowed farmers to reflect on decisions taken and to make prompt adjustments where possible. But discussions on improved preparedness were the most crucial component of successful farming. These discussions were supported by timely provision of weather forecasts, climate predictions and other science-based information. For example:

- ✓ Swiss chard producers in Ladybrand (Mr. Kobo), Brandfort (Mrs Mahlangu), Thaba Nchu (Tswelopele Veggy Project), Soutpan (Mr. Martinis), Sannaspos (Mr. Ncangiso) and others, raised concerns about the reduction of leaf development in winter season as it resulted in poor supply of bunches to the market. Continual supply is only satisfactory during summer season. These farmers were encouraged to invest into frost nets as improved preparedness to allow continual and frequent market supply for both seasons, not only for the summer.
- ✓ In Woon Huis supplementary irrigation was introduced in a 2 ha area and sequential planting was adopted. The 1st transplanting was in the 2nd week of July when15000 plants/0.5ha of Swiss chard was transplanted. The 2nd transplanting took place in the 2nd week of September with again 15000 plants/0.5ha The 3rd transplanting was in the last week of November, whereby 20000 plants/0.5ha were transplanted and the last transplanting was done in the last week of December with 35000 plants/ha. The plants transplanted in September suffered frost burns, which were caused by the black frost

that occurred within the second week of July 2008 just after the first planting. The frost chart was also explained to assist on selecting frost free days (Appendix frost probability chart1.4). Agrometeorologists recommended a frost protection net by April 2010, as frost preventative measure and to control frost damages. Continual supply was experienced and the income increased. Sufficient money was raised for expansion and crop diversification, when cabbage and onion seedling were planted 36000 plants/ha cabbage and 40000 plants/ha onions during winter season (also see Chapter 4).

- ✓ Most farmers, who only chose to supply cabbage, were able to make adjustments and introduce different cabbage cultivars for winter and summer season. Sequential cropping was also adapted by famers for continual supply to the market. For example, Mrs Lindlebele in Lakeview, which is part of Bloemfontein, owns an about 6ha smallholding farm (Table 5.1). In 2009 she was farming and producing for household consumption. Her participation and persistence in our workshops awarded her a great deal. She has employed four man and 2 women on her smallholder farm. In her words, I quote "The commitment of the researcher to teach us on using agrometeorological information has changed my life as a women and the life in my home, by just learning and working hard on the plot". She received advisories through e-mail and had learnt to work with it. The unique character of this farmer is that she is determined, hard-working and passionate about farming. She implemented recommendations given to her since the 2011/2012 season with support from intermediaries:

Table 5.1 An example of sequential cabbage planting adopted by farmers in the study area

Planting date	**Cultivar**	**Number of hectare**	**Plant density**	**Harvest**	**Estimated income @ R3/head**
15 October	Summer	1	36 000	35 000	105 000
15 November	Summer	1	36 000	35 000	105 000
30 November	Summer	1	36 000	35 500	106 500
15 December	Summer	1	36 000	35 000	105 000
March	Winter	1	36 000	35 500	106 500
April/June	Winter	0.5/1 (available field)	15 000	14500	43 500
Total					R 535 000

- ✓ Responding to tailor-made advisories developed for Thaba Nchu, farmers negotiated with the Ministry of Agriculture through Extension Agents for plastic tunnels. After 6 months the tunnels were erected for vegetable production under cover. This recommendation was prompted by very dry conditions in summer and very cold conditions in winter. Mr. Tloale mentioned that he once lost tomato plants of 0.5 ha when unexpected frosts were experienced.

- ✓ Beans and green beans producers across the study area raised a concern about experienced situations of water logging after above normal rainfall prediction that also actually occurred. The farmers were advised to select other types of crops such as maize and pumpkin which are more resistant to water logging.
- ✓ Livestock farmers appreciate skilled above normal rainfall predictions since it gives hope for revitalized pasture growth for animal grazing. But worries came with the 2010 outbreak of Rift Valley Fever and other diseases related to above normal rainfall conditions. For predicted drought conditions farmers prepare timely for supplementary feed, provision of water supply in drinking points and shelter for shade to minimize the possibilities of heat stress.
- ✓ Wheat producers in Koffiefontein and Thaba Nchu appreciated the provision of agrometeorological advisories since they were able to prepare their activities based on the short-term predictions for within the season activities and beyond harvesting. What happened in the past was that heavy rains occurred when wheat grains were just about a week before maturity. Such continuous rains that were not expected interfered with growth to full maturity as the grain seeds began to sprout prior to harvesting.

In partnership with the agronomy wing of the Agriculture ministry in the province, upon outbreak of diseases and pests farmers were provided with prescribed chemicals. The role of the agrometeorologist was to ensure that spraying was conducted on dry days, with the benefit that the chemicals sprayed were not washed away by water, and that spraying was not done during windy days.

Leaders took the responsibility of a facilitator during the final workshop (Table 5.2), regardless of a huge gap in the study group as to their level of formal education, ranging from no education to university education. They were able to conduct the task at hand. The same applied to the farmers from different educational levels as they were able to learn new science based information. Farmers were able to grasp different concepts and logic during the decision making with reference to past experience. This applied to concepts such as response farming, pest and disease management, fertilizing, weed control, soil cultivation and others. Most farm owners that participated in these study groups already acquired experience from their previous work on farms since they had been employed by other farmers.

Table 5.2 Profile of the study group leaders across the south-western Free State

Study group	Study leader	Age	Highest education	Daily activities	Training
Dewetsdorp	Mrs Jankie	45	Matric	Farming, Trader	Weather forecasting Climate predictions
Sannaspos	Mr. Mokhethi	72	Diploma in Policing	Farming Trading	Agrometeorological knowledge and understanding
Brandfort	Ms. Moshoane	41	Degree in Animal Nutrition	Extension	Agrometeorological knowledge and understanding
Soutpan	Mr. Martinis	74	None	Farming	Agrometeorological knowledge and understanding
Bloemfontein	Mr. Hadebe	42	Farm manager	Farming	Agrometeorological knowledge and understanding
Thaba Nchu	Mr. Tau	51	Matric	Farming, trader	Agrometeorological knowledge and understanding
Botshabelo	Mr. Pule	63	None	Farming, trader	Agrometeorological knowledge and understanding
Verkeerdevlei	Mrs. Nikelo	56	Std 4	Farming,	Agrometeorological knowledge and understanding
Jagersfontein	Mr. Jacobs	38	Matric	Farming	Agrometeorological knowledge and understanding
Koffiefontein	Mr. Rens	37	Matric	Farming	Agrometeorological knowledge and understanding
Tromsburg	Mr. Mokoena	57	Std 3	Farming, trader	Agrometeorological knowledge and understanding
Ladybrand	Mr. Kobo	65	Matric	Extension	Agrometeorological knowledge and understanding

The most valued strengths of the project were the farmer's newly found agrometeorological skills for on-farm decision making and the better understanding of the roles of different stakeholders. Study groups exchanged information by visiting other farms for learning by observing, to be encouraged. In some instances agrometeorologists took pictures during on-farm visits. Such pictures were used as examples and for further learning. The in-field training for farmers and organized special workshops for extension training were the successful tools for knowledge transfer. For example, during the on-farm installation of Automatic Weather Stations (AWS) in selected few farms in Sannaspos (2), towards Ladybrand (1) and Petrusburg (1) in-field training occurred, giving farmers knowledge and understanding.

5.4 The south-western Free State extension approach

The concept of an extension agrometeorology approach (Stigter and Winarto, 2012) holds great possibilities to train farmers on the application of science-based information. During the course of the study farmers in the study area were trained by agrometeorologists, but training of extension agents should be enforced for the proper training of the end-users. Agricultural success is established by the implementation of recommendations made on advisories and by the establishment of agrometeorological services leading to a significant decrease of losses and increase in production per farm. Despite the imbalances that transpired of the number of farmers per extension agent in the south-western Free State, training should be emphasized for improved production. Such imbalances should be remedied.

Science-based knowledge and understanding as support for developing solutions for agricultural decision making is generated from universities, agricultural research organizations, meteorological services and other environmental services institutions. To clarify the process on agrometeorological information/advisories/services generation/development by intermediaries for farmers as end-users, Stigter's conceptual and diagnostic framework applies (Figure 5.3). This framework consists of three pertinent domains: the contemporary pools of knowledge, extension intermediaries (and their supporters) and end-users (the livelihood of farmers) which are known as C, B and A domain respectively. This framework elaborates on two-way information exchange from basic scientists to extension intermediaries (and applied scientists supporting them), and from the latter to farmers and their livelihood systems. So the A-domain represents the livelihood of farmers into which agrometeorological services should be established. The B-domain represents the process of advisory/knowledge/services generation with the involvement of intermediaries to train the farmers. The C-domain represents a pool of science-based knowledge (Stigter et al., 2000; Stigter, 2005; Stigter, 2006; Stigter, 2010).

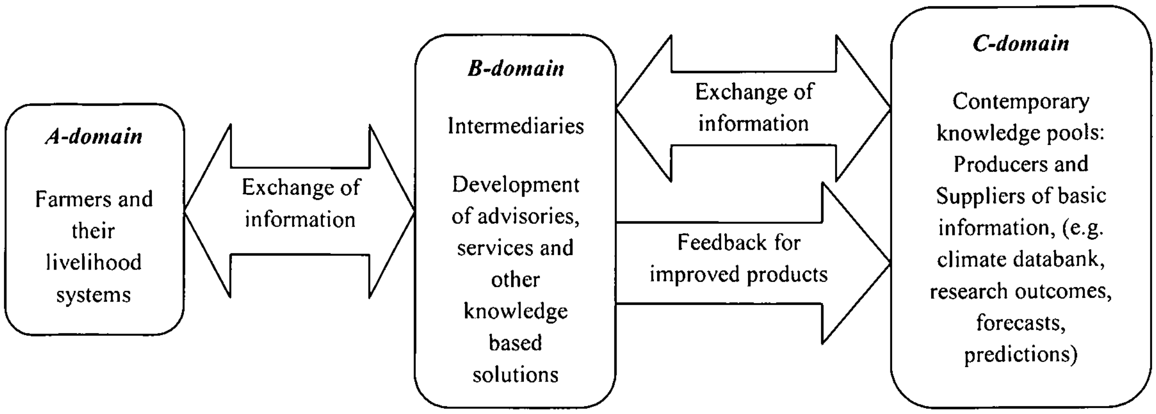

Fig. 5.3 End to end information flow resulting in problem solving in the livelihood of farmers. In the B-domain extension intermediaries are involved in producing solutions that can be applied in the livelihood of farmers (Stigter, 2006; 2010).

This end to end model was indirectly witnessed for the duration of this study. In the C-domain, different types of basic and derived knowledge such as long-term climatic data, soil characteristics, frost probabilities, climate bulletins etc. were used to run models and generate other knowledge in that C-domain. The results were used for the development of advisories and services (solution scenarios) in the B-domain. These advisories and services were contributed to and reviewed by intermediaries and applied scientists and were proposed to farmers and to the immediately related extension agents in the A-domain. Research in this regard played different roles, purely supportive in the C-domain and applied, solution oriented, in the B-domain. The advantage of this picture of reality is that applied research is directly involved in understanding and solving the frustrations and challenges of the farmers. The disadvantage is that this is too big a load of work for only one portfolio. Therefore, training of extension agents becomes crucial to learn about the development of advisories and services and how to apply them with the farmers.

The use of participatory tools was introduced to understand the livelihood systems and farming systems during training workshops with the farmers. In the previous discussions it was clear that farmers were not well-equipped for the interpretation of weather forecasts and climate predictions and for the application of other science-based information, while the same was the case with the extension agents. Therefore, more focus should be directed in the B-domain towards the training of extension agents. Such an intensification of training of intermediaries is the only solution to close the gap between the A-domain and the B-domain, finally using contents of the C-domain also to the benefit of resource-poor farmers.

An example from my research diary is presented in Box 5.4 on two farmers of which one was equipped with the application of agrometeorological information/advisories/services and the other was not. Ignoring the importance of training extension agents has a clearly negative impact for the farmers of their concern. Good decision making supported by the application of agrometeorology awards farmers with better yields (Box 5.4).

Box 5.4 Example emphasizing the importance of agrometeorology in decision making

During on-farm visits, I identified that the crop status of resource poor farmers was below average and of low quality for the 2008/09 season compare Appendix 1A. Although it was a season of good rainfall, with above-normal rainfall predicted and experienced. Advisories were now developed to guide the farmers based on the seasonal condition for 2009/2010, where for the October-November-December (OND) and for the November-December-January (NDJ) periods the rainfall forecasts were below-normal, but for the January-February-March (JFM) period above-normal rainfall was expected. Advisories entailed recommendations on crop type selection, cultivar selection, planting date selection and basic management strategies. Late planting of a cultivar with a short maturing time in the last week of December 2009, with increased plant population, were the recommended options under these late above-normal conditions. However, not all farmers took heed and delayed planting. For example, Mr Mokhethi in Sannaspos planted on 30 November 2009 and harvested 1-2 ton/ha, while Mr. van Tonder planted on 27 December 2009, three days before the actual onset of rainfall, and in July 2010 he harvested 2-3 ton/ha compare Chapter 4).

Therefore, as also follows from Fig. 5.3, in the south-western Free State case study it was discovered conducive to separately consider information producers, intermediaries and end-users. The system of extension approach of the Department of Agriculture can be effective by training extension agents to train the farmers. The extension agents are capacitated to travel and interact with farmers at least twice per month. Applied scientists working with the information producers such as the universities, agricultural research organizations, weather services and other stakeholders involved should focus on the following responsibilities:

- ✓ Make tailor-made products which are relevant, user-friendly and translated into local languages
- ✓ Train extension agents on the application of agrometeorological information/advisories/services during Extension Forums
- ✓ Implement a feed-back system to continual improve the status of what is used and done with the farmers by the extension agents.

Extension agents, which we can safely call intermediaries, should focus on taking part in this new extension agrometeorology approach, for which we must take care that they are now well-trained, and they should focus on the following tasks:

- ✓ Training of farmers during on-farm visits and study groups
- ✓ Where necessary and possible arranging with information producers to conduct in-field training for farmers with the extension agents being present (this method was baptized "Science Field Shops" by Stigter and Winarto (2012) in Indonesia and has been successfully applied there since 2008).
- ✓ Giving feedback to the information producers for further improvements according to the needs of the farmers.

The above approach will be complementing and improving the extension approach which is now operational and already established. The most important factor is to equip extension agents to be able to transfer/establish agrometeorological information/advisories/services to/with farmers. The approach will build more confidence into local extension agents.

Chapter 6

General Conclusions and Recommendations

6.1 Conclusions from Chapter 1

This study sought to demonstrate how commercial and resource poor farmers from the south-western Free State, synonymously used in this study as Modder/Riet catchment, during and after this study used weather forecasts, and climate predictions for agriculture and other science-based agrometeorological advisories in the area.

Pointing to the case studies presented in Appendix 1A, it must be concluded that the agricultural management of most participants at the beginning of the study 2008 was very poor. Information exchange with the farmers was made possible by establishment of qualitative research methods, which were carefully selected. Referring to case studies in Appendix 1A, it is without doubt notable that the resource poor farmers were rather in a desperate situation compared to the commercial farmers.

The thesis especially exemplifies case studies linking science-based products/advisories and problem solving in the agricultural production environment for various farmers, where applicable through extension intermediaries. This particularly contributed to increasing the useful operational applicability of weather science, climate science and various fields of agricultural sciences. This must be seen as a contribution to science itself.

As done throughout this thesis and explained in the first Chapter, it was very useful and necessary to see the clear differences between making available agrometeorological information, agrometeorological advisories and agrometeorological services.

Usage of agrometeorological advisories/products, for agricultural tactical and strategic operational planning, results in improved agricultural production for the benefit of farmers. As a consequence, at least part of the produce can be sold to generate income and household consumption, thus improving the livelihood of farmers.

To narrow the gap between the two groups of farmers the following recommendations should be taken into consideration and implemented.

6.2 Recommendations from Chapter 1

Weather forecasts and climate predictions for agriculture and other science-based agrometeorological advisories should be used to guide the farmers in terms of which response action/decision on agricultural activities to take. Such agrometeorological advisories should serve a crucial role in strengthening sound decision-making and sustainable food security.

As was the case for the study area, different bodies should collaborate to develop appropriate products, establishing suitable channels of information/product dissemination, and vital effective communication. It is therefore also recommended that agrometeorological advisories/products (and where possible services) be more generally instated in this study area, to transform the agricultural status of commercial and in particular resource poor farmers.

It is evident that local traditional knowledge has its limitations towards successful, productive and sustainable farming but should be taken serious where still in use.

It is also recommended that mentorship for farmers should be organized.

It is further recommended that extension agents are trained on the application of agrometeorological information/advisories/services to be able to properly transfer knowledge to the end-users (in this case farmers).

Expansion of agrometeorological weather stations is advocated for information developers to produce more tailor made advisories.

6.3 Conclusions from Chapter 2

This study revealed that most farmers in the south-western Free State are not familiar with the application of weather forecasts/climate predictions for agriculture and other science-based agrometeorological products but relied on their experience and traditional knowledge for farming decision-making. Most commercial farmers, having more resources, performed better compared to the resource poor farmers.

The majority of farmers in the south-western Free State prior to this study regularly experienced devastating disasters that were weather and climate related, such as rainfall scarcity and rainfall irregularity, floods, untimely frost events, wind storms that also perpetuated destructive wildfires, outbreaks of diseases and pests, uncontrollable weeds which required intensive labor, severe drought conditions and overgrazed grazing lands.

During the study groups, on-farm meetings and field schools, farmers demonstrated a great eagerness to learn about science-based agrometeorological information/advisories/services. Exchange of information took place since farmers shared their knowledge on traditional forecasting and decision-making.

Farmers used weather-related indicators in their traditional forecasting (mostly of rains and droughts) such as animal behavior, appearance of certain bird species, sprouting of aloe and other indigenous trees, accumulation of clouds, cloud types, appearance of certain insects, star constellation, shape of the moon and wind speed and direction.

Agricultural decisions were made according to traditional knowledge and understanding of environmental conditions of their local area obtained through years of experience. Understanding of the farmer's perception on climate is a critical step to facilitate effective communication on agrometeorological information/advisories/services.

It was discovered that variation in farmer's knowledge was based on age, farm experience and literacy. This knowledge is passed on through older generations during informal conversations and observations during the planting season. Farmers have been using different strategies to mitigate and cope with uncertain weather and climate conditions guided by their experience and wisdom acquired from previous generations.

The remaining challenge for agrometeorological advisories/services providers is to supply reliable and skilled forecasts/predictions through dissemination methods that suit the farmer such as local radio stations, television, news papers, cell phones and by e-mails to those who have access to the internet.

Long before the initiation of modern scientific methods for weather forecasting and climate prediction, farming continued successfully when impacts were not too severe. However, training on the application of agrometeorological advisories such as weather forecasts and seasonal predictions for agriculture, crop suitability, planting date, planting density, cultivar selection and other related decisions was very informative for the farmers, since they realized that such science-based knowledge was ultimately more suitable and more reliable than traditional knowledge.

Integration of agrometeorological information with local knowledge on weather forecasting and climate prediction may improve adaptation strategies and ensure that new information, products and services are implemented at farm level.

6.4 Recommendations from Chapter 2

Researchers engaged in such studies as ours should be people well equipped to incorporate sociology and farm management approaches, with participatory tools, in support of the farmers. They should, however, also have a scientific background, because the work is a combination of qualitative and quantitative research types.

Training of farmers is recommended in the interpretation and application of weather forecasts and seasonal climate predictions for agriculture and other science based agrometeorological advisories/products for farming decision-making. Because adaptation to increasing climate variability is essential to minimize consequences of more serious climate risks, and improved preparedness is essential for getting nearest possible to sustainable crop and animal production.

The following steps can be recommended for access to farmers in the whole of the Free-State Province:

- ✓ Step 1. Identification of Extension Officers for selection of target groups in the south-western Free State, to obtain permission to interact with the local producers through extension officers and selection of the target groups.
- ✓ Step 2. Needs analysis in terms of agrometeorological information/products/services, methods of information dissemination and traditional climate predictions of rainfall forecasting through participatory tools and techniques.
- ✓ Step 3. Focus on the existing channels of information and exchange of traditional climate predictions used by the farmers.
- ✓ Step 4. Farmers were informed on different topics related to agrometeorological information/products and sharing of weather/climate information as an alternative and good relationships were built with the farmers.

It is to be recommended to organize meetings with the farmers and stakeholders from different sectors to come and inform the farmers on their role in the community, e.g. fire fighters, bank representatives, food processors, animal producers, members of agricultural unions and successful commercial farmers.

The best outcome of this study was that farmers learnt new things and shared their information and experience. Through the process of interacting with other farmers, farmers learnt and steadily adapted the application of weather/climate information/products and other science-based agrometeorological information for agricultural decision-making. This farmer to farmer extension should be recommended for reaching the highest number of farmers in an area.

This study can recommend that participatory interaction with the farmers using focus groups, buzz questions, word of mouth, study groups and workshops allows two-way participation. This helps to understand the user's perception of the advisories, it allows a platform for constructive criticism that should lead to improvement of products and introduction of actual services, which are user friendly and translated into vernacular languages.

Training intermediaries well must be recommended because they are essential to carry this mandate for the improvement of management practices across the farming community. The institutions and networks for development and dissemination of information/products must improve their services, with the aim of making sure that these services get to the users and they must provide channels for feedback. It is still highly recommendable to improve the dissemination networks and establish feedback opportunities to facilitate the two-way communication amongst disseminators and farmers and other end-users.

6.5 Conclusions from Chapter 3

The tendency of scientists to develop knowledge for journals in the library that do not reach any end-users should be changed. It is therefore the responsibility of researchers and intermediaries to ensure that farmers have access to quality information/advisories/services for the betterment of agriculture in the Republic of South Africa at large. The study divulged a noticeable gap between the producers (universities/research institutes/weather services and other environmental services) and suppliers (broadcasters, extension officers, other intermediaries) of information/advisories/services while the users are in bitter need of agrometeorological products for improved on-farm decision-making.

The analytical results from questionnaires conducted in 2008 and 2012, with partly overlapping farmers, indicated that farmers in the south-western Free State differ in agricultural practices, interests, needs, experience and skills. Therefore, we need provision of tailor-maid agrometeorological advisories/products for crop production, animal husbandry, agroforestry and veld management.

The study identified potential production areas for vegetables, herbs/spices, grain food, oil seeds, fruits and other products such as cotton and other fibers. Application of crop models such as Ehler's, and Eco Crop revealed the thermal and water requirements of these crops which are either fully or partially met in various parts of the catchment. Agricultural production in some parts of the study area can be optimal under supplementary irrigation and where soil requirements are suitable.

Analyzed long-term rainfall data assisted the farmers to select suitable crops for the area for diversification and sequential planting and determining the suitable planting dates and planting densities. Crop models were used to generate and evaluate a series of management practice scenarios. These outputs from the analyzed climate data and crop models were used to develop advisories that were tailor-made for the farmers. The decision trees handled in the last Appendix were also used to develop alternatives of agricultural management practices for different seasonal climatic conditions.

6.6 Recommendations from Chapter 3

The application of agrometeorology on-farm is a concept that needs to be well-taught to the farmers and other users. This recommendation springs from the experience that during this study, agricultural production was hampered by poor farm management and lack of support to farmers. This was observed during transects walks on farms. When we implemented the study it became clear that we were pioneers in learning the farmers on the availability, reliability and application of agrometeorological information/advisories/services for agricultural planning. Others should follow here.

It is recommended that the Free State Agricultural Disaster and Risk Management Directorate trains some of their staff on agrometeorological information/advisories/services and also recruits an agrometeorologist to be effective and deliver tailor-made advisories.

It is also recommended that the ADRM should identify agrometeorological services providers within the Free State and form quarterly forums to initiate advisories and establish services with the farmers that are locally suitable rather than relying on advisories provided by the

National Directorate for Agricultural Disaster and Risk Management. Training of extension on these matters is another most critical thing to be considered in the near future.

It is further recommended that the SAWS, ARC and the Agricultural Ministry in the Free State should consider the expansion of Automatic Weather Stations into a controlled and maintained climate databank, managed by the Free State ADRM, that is freely available to the users (such as agrometeorological product suppliers), but also to the farmers, once they are trained to handle such raw information.

It is recommended that an early warning system is made possible through the ADRIM. Such a Unit should be made operational in the study area for increasing preparedness of farmers so that possible interventions can be implemented timely to minimize risks.

Intensification of agrometeorological workshops, meetings and information days for the training of extension agents for proper interpretation and establishment with farmers of the use of weather forecasts, climate predictions and other science-based information for user-friendly tailor-maid advisories is highly recommended for improving the agricultural status in the south-western Free State.

It is recommended that trial applications of weather forecasts and climate predictions for agriculture are not only guided by extension intermediaries or (for some time) scientists to establish their use but will also be followed up by a comparison of forecasts and predictions with the actual weather/climate experienced for the periods concerned. This will show skills as well as limitations of the forecasts/predictions available.

6.7 Conclusions from Chapter 4

The sustainability of commercial and resource poor farmer's livelihoods is very delicate and unstable. Therefore, it is imperative to consider this delicacy. The impact of development initiatives needs to be assessed in this context. Basically the development initiatives for agricultural sustainability should allow farmers to become in a position to preserve natural resources. To be able to develop viable initiatives, need analyses from farmers is one most important factor.

To contribute to the improvement of sustainable agricultural productivity and livelihoods, it is necessary to address the following types of needs, of which some have been dealt with already above, felt by the commercial and resource poor farmers in the south-western Free State:

- ✓ more secure access to and better management of natural resources
- ✓ more secure access to financial resources
- ✓ improved access to suitable agricultural technologies and information
- ✓ more support from extension agents and agricultural ministries
- ✓ understanding different stakeholders involved in agricultural development
- ✓ access to agrometeorological information/advisories//services and other science-based information
- ✓ speedy processes for obtaining land
- ✓ rehabilitation and installment of irrigation systems on farms
- ✓ transportation of agricultural products and access to markets
- ✓ support in obtainment (or subsidies for) farm implements
- ✓ mentorship and training on farm management skills
- ✓ sequential planting to meet market demands
- ✓ Eradication of animals roaming around the residential areas
- ✓ control of wild animals that destroy maize and wheat in some areas
- ✓ fencing of farms

In this context, it is a necessity to go further than evaluation of research performance in terms of agrometeorological advisories/services delivered and related decisions made by the farmers. Agricultural advancement is as much a social, political and institutional process as a technological one. For this reason, other stakeholders' perceptions and efforts are required, as perceived, understood and appreciated by farmers, for successful decision making.

Farm households are subjective to make certain adjustments in their choices of technologies, of support information and of types of farming production. These coping strategies can be grouped into three categories:

a) options such as choice of drought-tolerant varieties, planting density, cropping systems and investment in water management
b) in-season adjustment of crop and resource management options in response to specific climatic shocks as they evolve, and
c) options that minimize livelihood impacts of adverse climatic shocks.

During the duration of this study, it was notable through observations and informal interviews that farmers who were not familiar with the application of the agrometeorological information/advisories/services were prone to be mostly affected by climate shocks. These non-trained farmers were not exposed to early warning and other advisories, related or unrelated to weather forecasts and climate predictions, and therefore they were not prepared to mitigate/maneuver agricultural strategies. They had no coping strategies in place for risks reduction. Therefore, abundant room exists to expand and train extension agents on the nature of this study within the present and into other areas across the Free State.

Impact assessment outlines the advantages and disadvantages of choices made, and investigates possible synergies for the development of suitable interventions that seek to reduce agricultural disasters. Impact assessment in this regard took place during the development of agricultural decisions based on the iterative steps of an action learning cycle. It may occur prior to the endorsement of a proposed or suggested intervention, or when the proposed intervention has been approved or it may occur in between these two stages of information generation. Of course ultimately it will also be used after the impacts occurred.

This study was an attempt to improve the status of agrometeorological knowledge whilst seeing to improve agricultural status with the application of agrometeorological information/advisories/services. The results or findings from the previous season were prioritized risk assessment to identify farmer's vulnerabilities and this basically was used as a starting point for the development of new interventions to alleviate the agricultural damages.

6.8 Recommendations from Chapter 4

Some recommended management decisions by farmers using seasonal rainfall predictions

Under predicted dry season (below normal rainfall)	Under predicted normal to wet season (normal to above normal rainfall)
1. Ensure land is cultivated timely prior to drier conditions	1. Ensure land is cultivated timely prior to onset of good rains
2. Order inputs (seedlings, seeds & fertilizer) prior to engaging in planting	2. Order inputs (seedlings, seeds & fertilizer) prior to engaging to planting
3. Concurrently check weather forecasts and climate predictions and draw an operational plan for the season	3. Concurrently check weather forecasts and climate predictions and draw an operational plan for the season
4. Minimize planting density by at least 25%-50% ha^{-1}	4. Introduce normal to higher planting density ha^{-1}
5. Minimize labour and other input use	5. Ensure there is sufficient labour and apply fertilizer
6. Plant just before the expected onset of the 1st rains	6. Adopt sequential planting and intercropping
7. Opt for drought tolerant crops such as sorghum & millet	7. Plant crop varieties (diversify).
8. Control weeds frequently	8. Control weeds more frequently
9. Introduce water conservation methods such as using different types of mulch	9. Strengthen the use of terraces and ridges/dykes to reduce erosion & surface run-off.
10. Minimize the area under cultivation	10. Enlarge area under cultivation
11. Apply (supplementary) irrigation where possible	11. Apply irrigation in the occurrences of long dry spells

It is recommended that for continuity and availability of agrometeorological advisories, such advisories and products can be sent to the extension director within the State Ministry of

Agriculture to be discussed during Extension Forums and then further be disseminated to farmers in the most suitable form and the most suitable way. Such a process will facilitate feedback from the farmers for the development of more tailor-made and more user-friendly advisories. [See for an extension of this idea the recommendation on a full procedure under Chapter 5 Recommendations.]

It is recommended that impact assessment for our types of study will be considered as follows. Agrometeorological knowledge impact assessment has two characteristics, which are the internal monitoring of continuous learning, in for example the exposure to the usage of weather forecasts, climate predictions and other science based-information. Farmers at all levels were introduced to different types of forecasts and were guided on their interpretation and application in agricultural decision making. Farmers were introduced into existing information management systems from different stakeholders responsible for the provision of agrometeorological information/advisories/services.

The internal ongoing learning was interlinked to the second characteristic, the external impact assessment, and the latter involved the development of interventions which were related to the use of weather and climate knowledge. Sets of interventions were developed and linked to agrometeorological advisories for improved agricultural production aimed at improving the economic status of the farmers. Preparedness through early warning systems must be considered one important factor to counteract climatic shocks. Also this part of the approach is recommended for application elsewhere.

6.9 Conclusions from Chapter 5

The study groups presented a very diverse situation in terms of experiences, challenges and needs that are related to their farming. The consequences of increasing climate variability needed greater emphasis as to farmer's ability to develop on-farm coping strategies and interventions. A successful farmer should understand the local trends in climate change and how agricultural outcomes are influenced. For example, the concept of response farming prepares the farmer to be aware of past and future climatic conditions and of the extent of increasing climate variability and related dangers and interventions to reduce vulnerabilities.

Agrometeorological information/advisories and, where people can assist to establish them, services, can be disseminated by sending them to key communication outlets that are readily used by most people such as television, freely available local newspapers, local radio, bulletins, ward committees, extension forums and early warning committees. Cell phones can be used where the message may have limited size. The agrometeorological details should entail relevant and tailor-made information/advisories/services that are directly useful to the farmers and the latter should be able to interact with the sources. For all farmers in the south-western Free State to embrace the use of agrometeorological information/advisories/services would ideally require the interaction with extension agents to obtain the necessary knowledge and understanding.

Participation of farmers in a series of monthly innovative workshops created a conducive environment for information exchange and training. It is advisable to conduct on-farm visits prior to the workshop/meeting days for proper preparations. This was to ensure that the monthly workshops were well-planned, productive and informative events. The manner in which this study was structured enhanced a bottom-up approach since it allowed participative approaches in close contact with the study groups, improving farming development by closing the gaps existing between developers, suppliers and users of knowledge and understanding.

In my experience as a researcher and an intermediary for the past five years, climate monitoring, record keeping and improved preparedness were the most emphasized issues during in-field training. Climate monitoring was emphasized with the use of rain gauges to measure rainfall and keep daily records. Two automatic weather stations were installed. Record keeping played another new role for farmers to record all activities implemented on-farm against time. This allowed farmers to reflect on decisions taken and to make prompt adjustments where possible. But discussions on improved preparedness were the most crucial component of successful farming. These discussions were supported by timely provision of weather forecasts, climate predictions and other agrometeorological science-based information for farming.

Leaders took the responsibility of a facilitator during the final workshop, regardless of a huge gap in the study group as to their level of formal education, ranging from no education to university education. They were able to conduct the task at hand. The same applied to the farmers from different educational levels as they were able to learn new science based information. Farmers were able to grasp different concepts and logic during the decision making with reference to past experience. This applied to concepts such as response farming, pest and disease management, fertilizing, weed control, soil cultivation and others. Most farm owners that participated in these study groups already acquired experience from their previous work on farms since they had been employed by other farmers.

Extension agents, which we can safely call intermediaries, should focus on taking part in this new extension agrometeorology approach, for which we must take care that they are now well-trained, and they should focus on the following tasks:

- ✓ Training of farmers during on-farm visits and study groups
- ✓ Where necessary and possible arranging with information producers to conduct in-field training for farmers with the extension agents being present (this method was baptized "Science Field Shops" in Indonesia and has been successfully applied there since 2008).
- ✓ Giving feedback to the information producers for further improvements according to the needs of the farmers.

The above approach will be complementing and improving the extension approach which is now operational and already established. The most important factor is to equip extension agents to be able to transfer/establish agrometeorological information/advisories/services to/with farmers. The approach will build more confidence into local extension agents.

6.10 Recommendations from Chapter 5

From our experience, we feel that the existing channels used for the NAC advisories and the manner they are developed need to be reviewed. In improved form it should address the specific recommendations for diverse groups of farmers and the extension agents should be able to discuss them with the farmers and get feedback.

To understand this recommendation one has to understand the following procedure and its flaws:

"The weather forecasters such as the South African Weather Services (SAWS), ARC-ISCW and other centers are also responsible for the development of the seasonal outlook. This information is sent to the National DAFF, where suggested agricultural activities from the farmers, through the extension agents, are incorporated into the seasonal outlook to develop a NAC advisory. This advisory is transferred back to the provincial DAFF to be sent to ADRIM, the unit that deals with agricultural risks and disasters. This NAC advisory goes through to the Early Warning Committee that is the body of expertise from different disciplines in which extension agents are represented, for cross-examination and double checking on its relevancy for the coming season. With the amendments and the approval of the EWC, the NAC advisory is forwarded through e-mails to the extension agents. They eventually have to reach the farmers to be used as the support tools for on-farm decision making. The NAC advisory guideline is too general and is not point specific, which makes it rather difficult for the extension agents to understand it and convey it to the farmers. This process provides no room for the feedback from the farmers to present their suggestions about the advisory".

This study proposes from the above a strategy to develop and transfer agrometeorological advisories from the national DAFF as follows:

a) to appoint a group of weather forecasters using different Global Circulation Models and including predictions from other International Climate Prediction Organizations (NOAA, IRI, APCC)
b) to request, where possible with sufficient skill and accuracy, downscaled climatic conditions per region at a high resolution
c) to hire a qualified team of agrometeorologists to develop tailor-made advisories per region and where possible per farm (see also Gommes et al., 2010)
d) information/advisories/services developers can interact with the extension agents to address the needs of the farmers at grass root level
e) development of tailor-made advisories which strengthen diverse farming methods and sustainable agricultural development
f) to implement conducive strategies of information dissemination as preferred by and suitable for the farmers
g) delegation of weather forecasters/climate predictors and agrometeorologists to train extension agents during their monthly regional Extension Forums
h) ensure dissemination of client friendly agrometeorological information/advisories/ services from intermediaries to farmers
i) strategize and develop a two-way communication from farmers to intermediaries so that farmers' concerns can be sent back to advisories/services developers
j) a two-way communication to give extension/feedback from farmer to farmer may positively influence the degree of application of agrometeorological information/advisories/services (as illustrated in Figure 5.2).

The better way of information dissemination that was discovered during the period of this study was the participation of intermediaries in the organized study groups per area. This platform encourages the interrogation and discussion of advisories for better clarity and good planning. The proposed strategy ensures open discussion and transparency from stages of information/advisories/services development to training of intermediaries and to the application of the ultimate results by the end-users. This strategy allows users from different levels of farming to be able to consider the relevance of agrometeorological information/advisories/services towards successful agricultural development. Ignoring the two-way communication may result in uncertainties and unnecessary information distortion. But with the provision of an open end situation, smooth flow and understanding of information/advisories/services may have outstanding results. The above should be recommended where organized study groups are chosen as a way to engage farmers.

It is recommended that information producers should consider developing web-based aggregated information from different sources in one format and present them in a single website which should be accessible to extension agents to draw information from. This web site should address the needs of the farmers in the south-western Free State and the Free State Province at large. The most basic value of such initiative will add to provision of agrometeorological advisories/products to farmers.

It is also recommended that agrometeorological courses should be incorporated in the extension curriculum at tertiary level for better understanding of the agrometeorological principles and their applications. Agrometeorology in South Africa and other developing countries is categorized as a scarce skill; this provides enough motivation for the planning of intensive agrometeorological workshops and roving seminars.

The concept of an extension agrometeorology approach holds great possibilities to train farmers and should be highly recommended. During the course of this study, farmers in the study area were trained by agrometeorologists, but training of extension agents should ultimately be enforced for the proper training of the end-users. Agricultural success is established by the implementation of recommendations made on advisories and by the establishment of agrometeorological services leading to a significant decrease of losses and increase in production per farm. Despite the imbalances that transpired of the number of farmers per extension agent in the south-western Free State, training should be emphasized for improved production. Such imbalances should be remedied.

Finally, from our experience, the following attitudes are essential recommendations for working with farmers.

Accommodating farmers from different backgrounds in study groups.
[Different groups in study groups were represented by the elderly, youth, women, men, resource poor farmers and commercial farmers.]

- ✓ Need to stay calm, focused and with good listening skills
- ✓ Remain sensitive and very patient
- ✓ Do not teach or appear to teach
- ✓ Be able to ask questions in local languages or organize for an interpreter should it be necessary
- ✓ Avoid appearing patronizing and try to be at the level of the participants
- ✓ Allow all participants to contribute
- ✓ Appreciate different contributions
- ✓ Plan everything with farmers in time and make sure the task at hand is well understood
- ✓ Where possible arrange different meetings for specific groups and attend to unique needs during on-farm visits
- ✓ Be attentive to behavior and level of participation
- ✓ Listen attentively to the stories of the farmers
- ✓ Ensure to address issues indicated by farmers at level best

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Appendices

Appendix 1A. Case studies of showing the on-farm situation we found at the start of the study

1. Crop status prior implementation of agrometeorological information for selected farms

On-farm visits were conducted concurrently with study group workshop to exchange information and discover challenges faced by an individual farmer. The first visits aimed at assessing the farm agricultural status, farming systems and agricultural enterprises to identify farmer's shortcomings with the aim to strengthen farmers' decision-making. This exercise led to a better understanding of the challenges experienced by the farmers on daily activities and identified factors that lead to poor production. Interacting with the farmers made it possible to reach consensus that poor agricultural production was a result of poor agricultural planning, poor management and lack of availability of agrometeorological advisories to guide decision development.

The farm status differed from one farmer to another since the farmers were different in terms of farm experience, capital and knowledge in farming.

Example 1: During the on-farm visit at Nikelo Farm, which is 200 ha in size, the observations were as follows:

- ✓ the maize crop was nearing maturity stage, had already tasselled but there were very small and abnormal cobs with few or no seeds at all,
- ✓ the planted field was covered by weeds,
- ✓ the maize plants were wilting and drying out before maturity stage,
- ✓ plant spacing was too condensed,
- ✓ plant rows were too close less than half a meter,
- ✓ small portion of land was planted and about 50 ha left unplanted,
- ✓ the maize was planted in a very shallow soil,
- ✓ the soil clay content was about 80% which makes it impossible for vegetable production,
- ✓ the wind mill pump was broken and irrigation was not possible,
- ✓ the grazing camps were overgrazed and poorly managed,
- ✓ there was no transport to buy inputs and to deliver products at the market,

- ✓ the farm was overcrowded with different types of agricultural activities from maize production, vegetable production, goats, sheep, broilers, free range chicken, geese, ducks, dogs, piggery and cattle production.

Picture 1. The status of maize production at Nikelo Farm in Verkeerdevlei taken in March 2008.

Example 2: A farm located in Sannaspos which is about 300 ha and used to produce 2-3 tons/ha of maize during the previous owner (Picture 2). The following observations were made:

- ✓ previous owner produced 2-3 tons/ha under rainfed conditions but in 2008 the farmer could only offer to cultivate a $4m^2$ for household consumption,
- ✓ no weed control measures were considered,
- ✓ the crops were drying out at development stage,
- ✓ the windmill was broken into pieces which made it impossible to use for supplementary irrigation,
- ✓ there was no proper planting plan in place,
- ✓ grazing camps were overpopulated and poorly managed,
- ✓ no access to agrometeorological information,
- ✓ no implements to cultivate the land and expand planted fields,
- ✓ no labour capacity to run tasks on farm,
- ✓ poor management of agricultural activities,
- ✓ no financing to buy inputs,
- ✓ lots of hectares were left unproduced due to lack of knowledge, farm management skills.

Picture 2. The farm status at Muyayi farm in Sannaspos taken in March 2008

Example 3: Kotle farm is located between two mountains and it can be very cold in winter as the cold air sinks into the valley. The farm produces maize, vegetables and livestock (Picture 3 (a) and (b)). The observations noted on this farm:

- ✓ this farm is encroached by trees, shrubs and stones and crop production on its land may not be possible
- ✓ the maize plants were stunted as a result of poor soil fertility and being shaded by the tall trees which minimize radiation penetrating to planted crops,
- ✓ lack of water sources for supplementary irrigation,
- ✓ the maize usually does not reach maturity stage and so it is fed to livestock
- ✓ the area is prone to hailstorms which destroys crops in each and every summer but trees are available to protect animal,
- ✓ well structured shelters for sheep, goats, cattle and horses that prevent animals being harmed from cold and other catastrophic weather conditions
- ✓ during hot days, there are enough trees to provide shade and prevent animals from suffering from heat and water stress
- ✓ proper management practices could improve crop status, seeing that most problems were weather related and provision of seasonal forecasts could help to develop a good

plan for crop production and to take precautionary measures against cold snaps where trees are at distance.

- ✓ It is advisable to continue with livestock production and crops should be produced for household consumption.

(a) 

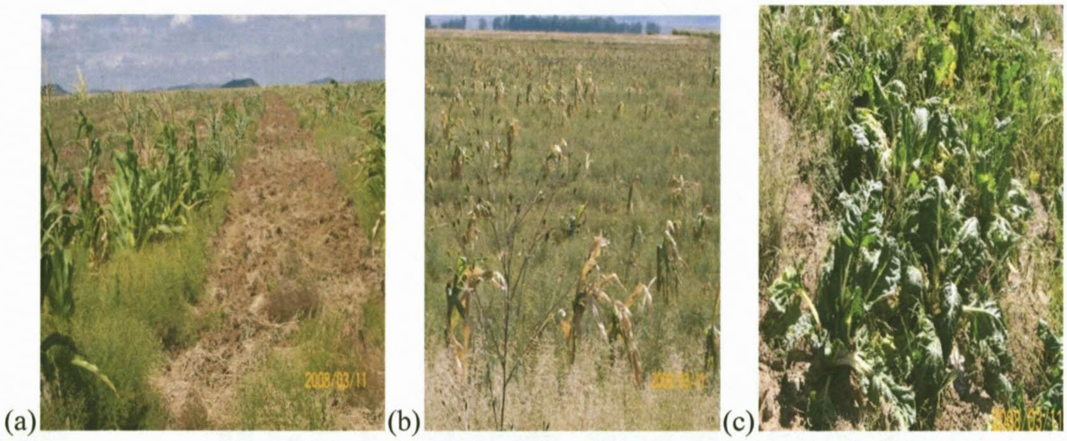
(b 

Picture 3 (a) and (b) The crop status at Kotle farm taken in March 2008.

Example 4: EMS farm is about 480 ha located in Sannaspos (Picture 4). The observations during first visits were as follows:

- ✓ We observed that peach trees are planted next to the mountain and there is a stream of water that runs down the mountain; the location can reduce the peach yield due to frost and strong winds,
- ✓ relocate the trees to another space or position on farm can result in better production,
- ✓ planting trees as windbreakers around fruit trees can reduce harsh winds by providing protection
- ✓ the grazing camps were overgrazed and it was recommended that the area extension agent should be invited to provide information via a veld management course,
- ✓ maize fields were in a poorly managed status full of weeds,
- ✓ about 50 ha of maize was planted but because of poor planning and management the crop condition was very poor,
- ✓ The field was infested by weeds and grasses, resulting in stunted growth and as for that season there was no yield at all
- ✓ the maize was planted on 10 January 2008 and by the time the picture was taken it should have reached reproduction stage, but 95% of the plants were drying out with few cobs,

- ✓ Swiss chard was planted at ½ ha and the plants were overrun with tweeds which resulted in plants competing for soil water, space and nutrients,
- ✓ the leaves looked curled, wilting and yellowish
- ✓ we reached consensus with the farmer to give training on the application of agrometeorological information/advisories/services and he was encouraged to attend study groups to learn.



Picture 4 (a) and (b). Maize and Swiss chard crop status at EMS farm taken in March 2008.

Example 5: van Tonder and Sons Farming are commercial farmers who have an experience of about 32 years in farming. He is a neighbouring farmer to EMS farm and owns about 180 ha located in Sannaspos (Picture 5). The observations during the first visits were as follows:

- ✓ maize production is the sole agricultural enterprise on farm,
- ✓ make use of weather forecasts, climate predictions, seasonal forecasts and other agrometeorological information from the internet
- ✓ has good understanding of local environmental conditions
- ✓ emphasized that the forecast nowadays has improved and is more reliable compared to the past 10 years
- ✓ major challenges are the weeds and the high cost of inputs.

The south-western Free State is a land of contrast. Picture 5 (b) clearly indicates that farmers may own the land but knowledge, skills and resources are the key to successful farming. These dissimilarities can be closed by providing resource poor farmers with agrometeorological information/advisories/services, which is what this study aimed to unpack. Picture 5 (b) is a demonstration of two farmers with different background for maize production. The good status maize production belonged to van Tonder, which was planted on the 5th of January 2008; the maize in a poor status was planted on the 11th of January 2008. There were differences in activity plans. One field was well managed, since no weeds were on the field and taken good care of, and the other field was neglected by the farmer.

Mr. van Tonder mentioned that successful maize production is based on the understanding of the soil type, selection of proper planting dates, application of the required fertilizers, selection of suitable cultivars and control of pests and diseases and one must have implements to cultivate the land, for harvesting and weed control and also have reliable labourers.

(a)  (b) 

Picture 5. Comparison of Mr van Tonder (a) and EMS farm maize crop status taken in March 2008.

Example 6: A commercial farm located in Soutpan area known as Esther & Sons, enthusiastic about maize production planted at three different planting dates. Serial Picture 6a shows a maize crop status planted during the last week of November 2007 that was harvested on 12 March 2008, and the final yield was good at 2-3 tons per ha. In Picture 6 (b) at the top edge of the picture maize planted on 20th December 2007. The maize was already at maturity stage and ready for harvesting for green maize. On the same picture the maize with the stunted, curly leaves with water stress symptoms and tasseling before time was planted on the 10th of January. The better yield was harvested from maize planted in November and December and the seasonal forecast indicated above-normal (in OND) and below-normal (in JFM) rainfall.

(a) 

(b) 

Picture 6. The impact of proper selection of planting date. Examples taken from Soutpan prior to dissemination of agrometeorological information.

Example 7:

For sunflower production planted at a scale of 16 ha, the observations were that the crops, although planted on the same date, were different in growth development. One kind appeared to have small sunflower heads (Picture 7 (a)), while sunflowers in Picture 7 (b) appeared to be in a perfect crop status with large leaves and big heads. This farmer had no access to or knowledge on seasonal forecasts but depended on his experience to run the farm.

(a) 

(b) 

Picture 7 (a) & (b). Sunflower crop status planted on the same day taken in March 2008.

2. Climatic conditions in the study area

Glen Agricultural College mechanical and automatic weather station used to determine the rainfall pattern since it had been operational since 1921. Based on the set standards of 30 years by the World Meteorological Organization (WMO) this study analyzed 57 years of rainfall data to quantify and present graphically the mean annual rainfall. The average annual rainfall for the Glen automatic weather station was calculated as 468 mm.

Reading from Figure 1, it is visible that the amount of rainfall received per year is inconsistent. In 57 years analyzed for the receipt of rainfall it shows that 56% of years received below mean and only 44% above mean annual rainfall. Also 7% were witnessed as driest years, which recorded below 300mm annual rainfall and had amounts that ranged between 190 mm to 274mm. They occurred in 1958/59, 1965/66, 1992/93 and 1999/2000. The wettest years in history for this weather station recorded an annual rainfall ranging from 635 mm to 828mm; this occurred in 1956, 1963, 1967, 1974, 1976, 1981, 1988, 1991 and 2006 (Figure 1). The mean annual rainfall variation shows that rainfall is not consistently near to a mean value but it differs from year to year with a wide range because of rainfall variability (Tyson & Preston-White, 2000).

Rainfall data analyses are critical for agricultural purposes to set boundaries for better planning for farming practices and crop selection. Mean annual rainfall trends can assist the farmer not to expect consistently around the same amounts of rainfall every year. It shows that annual rainfall fluctuates and extremes can occur (in 1992/3 it was about 190mm, and in 1988/89, 1990/91 and 2006 over 800mm were received) (Kruger, 2004). Under these conditions, the farmers must be prepared with coping strategies to minimize or avoid crop failure and loss of livestock.

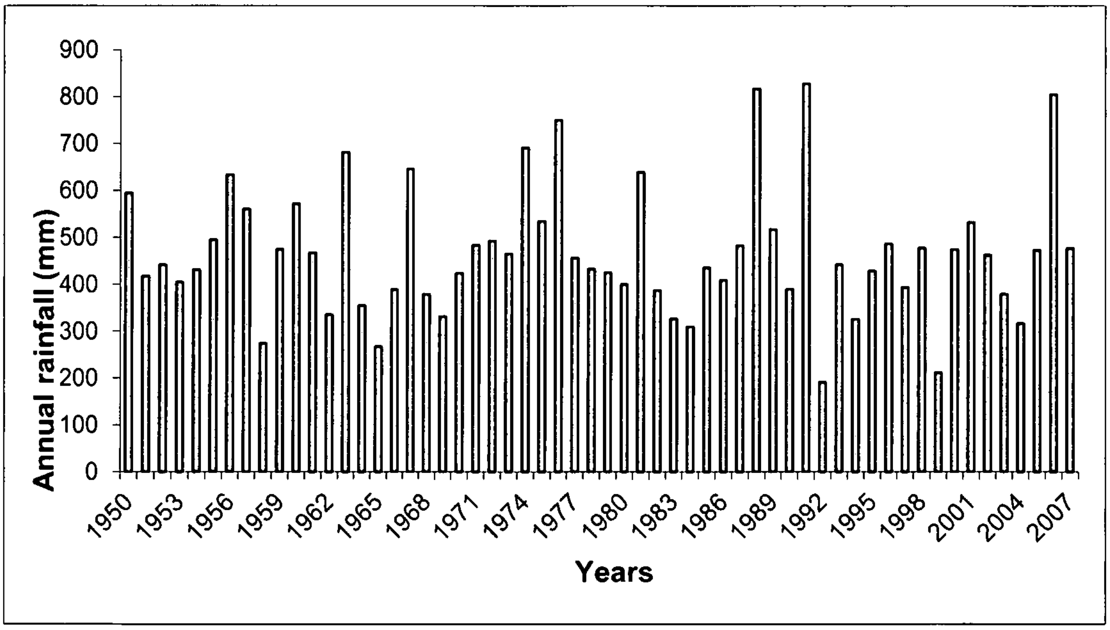


Fig. 1 Long-term annual (June to July) rainfall for Glen Agricultural College weather station

The mean monthly rainfall trend presented in Figure 2 shows that sufficient rain, >45mm per month may be expected from October to March. For the crop growing season monthly rainfall amount is increasing from 45 mm to 73 mm. The amount of rainfall received from April to September decreases from 42mm in April to between 6mm and 8mm from June to August and there is only 24mm in September. In summary: the seasonal average rainfall for this area is 468 mm, received mainly during October to April (Table 1.).

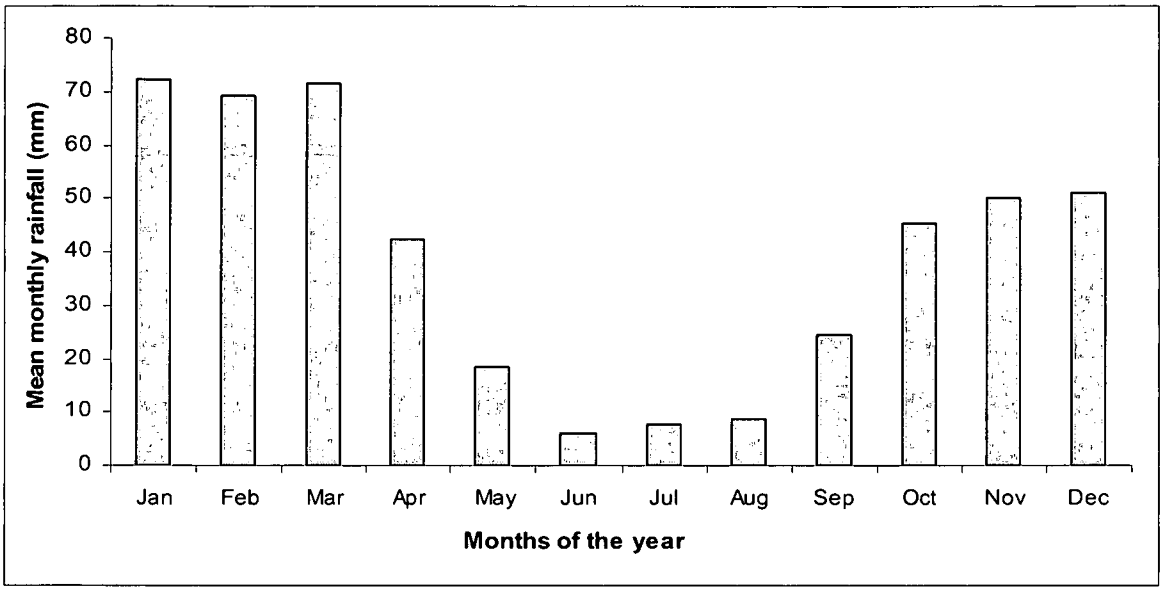


Fig 2 Long-term mean monthly rainfall trends for Glen Agricultural College weather station

3. Probability of dry spells

Information on dry spell longevity is crucial to prepare for supplementary irrigation, to establish water conservation techniques and to make decisions on which agricultural activities to undertake such as weeding, transplanting (Diga, 2005; Fischer & Savenije, 2009). The best time to plant can be determined by using the lowest probability of getting prolonged dry spells (Wilks, 1999). That is, prior to planting the farmer has to ensure that soil water content is optimal. Figure 3 shows the probability of occurrence of 7-days, 10-days and 15-days dry spells during the September to March spring and summer season for Glen Agricultural College weather station.

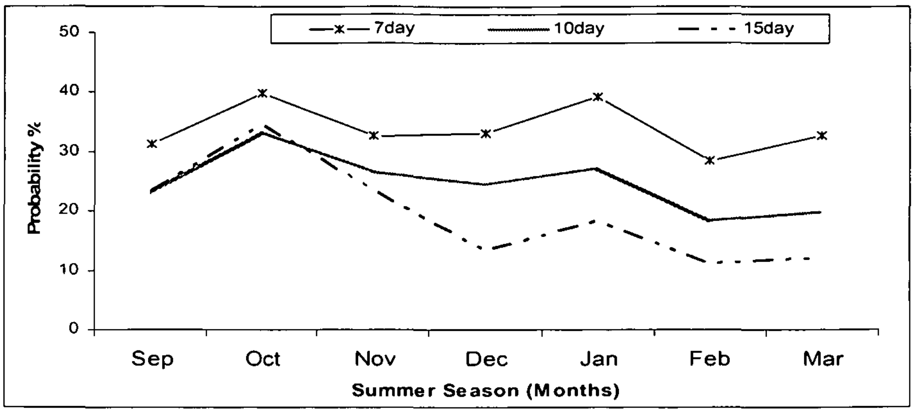


Fig 3 Probability of dry spells of varying length (7, 10 and 15 days) during the spring and summer rainfall season for Glen weather station

At the beginning of the season during September and October there is a 30-40% probability of experiencing a 7-day dry spell. This means that once in 2.5 till 3.3 years one can expect to have a 7-day dry spell during any of the spring rainfall months. Considering the probability of a 15-day dry spell, it is relatively higher in spring, with a 25-35% chance, but then decreases later in the season, in summer, to a 11-12% chance during February and March. This is in line with a higher rainfall amount received during those months indicating that the daily amounts probably do not differ, but the interval between rain days is reduced. The probability of a 10-day dry spell first ranges from 19-33% with a reduced chance later in the season. Consequently, the decreasing chances of 10-15 days dry spells are critical and the rainfall received will be beneficial for crop growth and development and help to avoid water stress. Optimal planting must take place when prolonged dry spells (10-15 days and above) have lessened, for example in December the 15-day dry spell probability is less than 15%, otherwise germination and emergence as well as initial crop vegetative growth may suffer due to severe water stress when roots are shallow. The highest critical dry spells occurred during October and decreased as the season goes except for the 7-day dry spells, as they remain between 30% and 40%. In addition, a seven days dry spell can be disastrous just after sowing. The probability of prolonged dry spells can assist the farmer to try to avoid water stress during crop sensitive phenological stages e.g. during germination and flowering. Should the crop suffer from water stress, the final yield can decrease, as reproduction will not occur (Shaw, 1987). For example, should the maize crop undergo water stress at flowering, this results in crop failure. Therefore, farmers should be advised to maintain soil water at root level for healthy plants.

Dry spell probability information can be of benefit to help farmers to plan for their in-season and off-season agricultural activities (Phillips, 2001). Dry spell occurrence information for a specified location is critical in selecting crop types and suitable cultivars that are drought resistant. Prior knowledge of dry spell probabilities assists in proper planning for application of fertilizer, mulch, adapting in-field or simple water conservation tillage methods and supplementary irrigation at appropriate times. But one should never forget that we work with probabilities, so reality may be quite different in some years. For operational planning, it can be used to select the best planting days, or days for hoeing, weeding, pesticide/herbicide spraying, and application of fertilizers. Dry spell occurrence information is therefore essential to farmers for tactical and strategic operational planning decisions, within the limits set by the use of probabilities. The dry spell probability information therefore has its advantages and disadvantages.

4. Rainfall distribution

The annual rainfall across Modder/Riet catchment ranges from 300–700 mm (Figure 4). The western towns of the catchment, Fauresmith, Koffiefontein, Luckhof, Ottosdal, Petrusburg and Riet River's annual rainfall ranges from 300–400 mm. The central interior area around Bloemfontein and Glen ranges from 400–500 mm and the eastern part of the catchment ThabaNchu and Botshabelo receive higher rainfall, which ranges from 600–700 mm. Monthly rainfall in mm is shown in Fig. 4 from selected rainfall stations within the catchment. Higher rainfall months start in November until March together with higher temperatures. However, winter months run from May to August with rainfall below 25 mm except for Fauresmith, which is below 33 mm in May with minimum temperatures of 5°C.

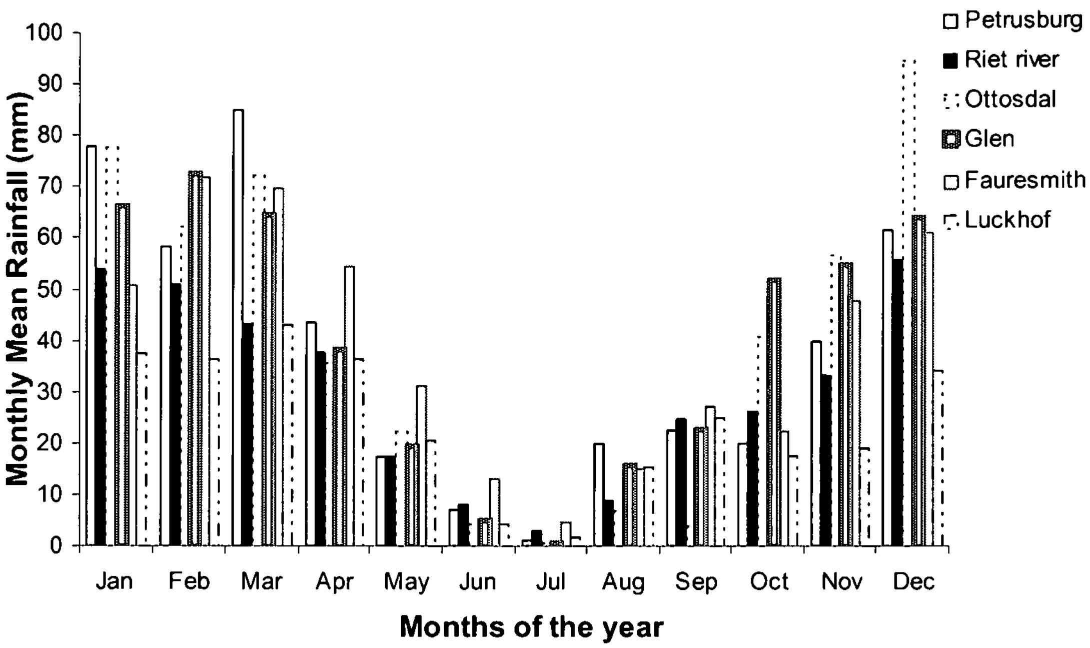


Figure 4. Annual rainfall for selected stations in Modder/Riet catchment

Weather stations in the Modder/Riet catchment have shown that none of the stations receives more than 100 mm in any rainy month. The peak rainfall months are January, February and March for all stations except Ottosdal, which peaks in December. The winter is mostly dry with June and July both receiving less than 10 mm at all stations, with minimum temperatures of 5°C and below (Figure 5). All stations receive an average of more than 20 mm in September and October but the rainy season only really begins with adequate rain for crop production in November. In the south-western Free State crop production activities begin as early as November for summer crops and in April for winter crops.

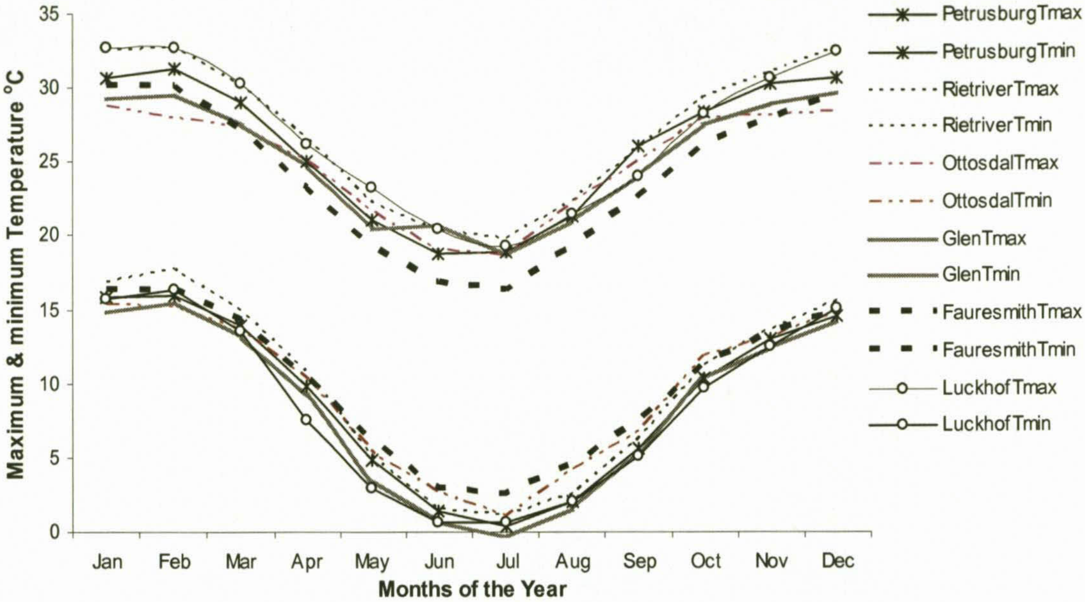


Fig 5. Monthly mean minimum and maximum temperature for the selected stations in Modder/Riet catchment (ARC-ISCW).

Appendix 1 B: METHODOLOGIES

a) Site description

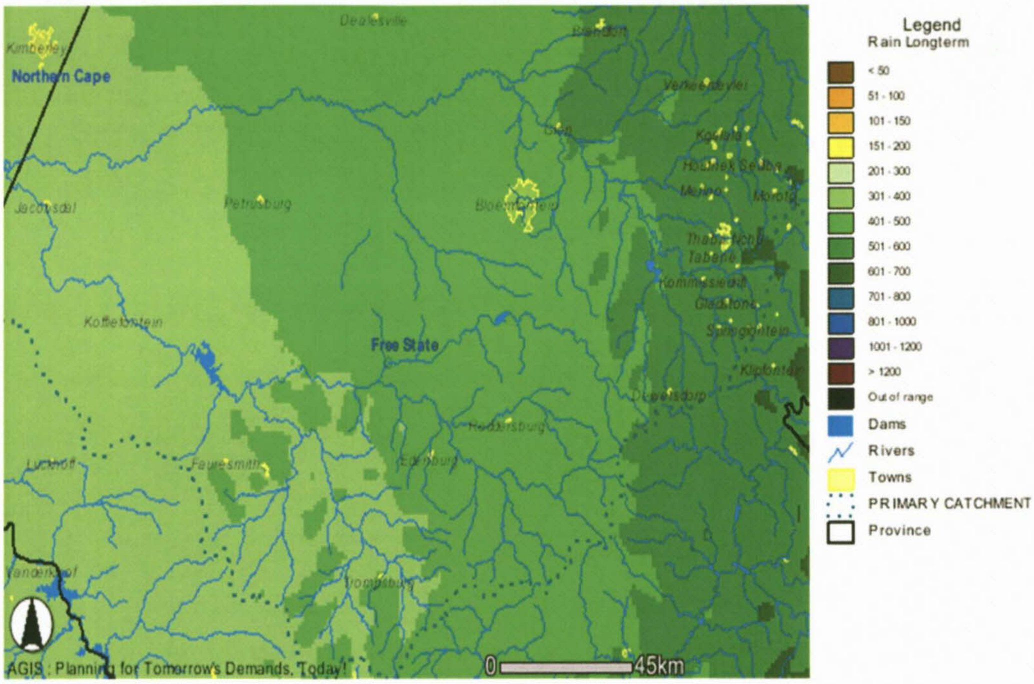
This study was conducted in the south-western Free State which is within the Modder/Riet catchment and encompasses part of Lejweleputswa and the whole of Motheo district. The Modder/Riet catchment covers an area of 2 827 286 km^2. The study groups were identified in the following town, Dewetsdorp, Sannaspos, Brandfort, Soutpan, Bloemfontein, Thaba Nchu, Botshabelo, Verkeerdevlei, Jaggersfontein, Koffiefontein, Thromsburg and Ladybrand.

The automatic weather station selection in the Modder/Riet catchment was chosen according to long-term data availability, agro-ecological zones and agricultural activities. The custodian of such climatic data is Agricultural Research Council-Institute for Soil, Climate and Water (ARC-ISCW) and the South African Weather Service (SAWS). The land type information was also obtained from ARC-ISCW.

Six climatic weather stations were available in the south-western Free State: Fauresmith, Luckhof, Glen, Ottosdal, Petrusburg and Riet River with the annual average rainfall ranging from 300 mm to 600 mm. The dotted line represents the catchment boundaries from the west, the south and the eastern part of the catchment (Map 1.1).

b) Land type information

The land type for the selected catchment class group is Dc13 according to land type groupings (Land Type Survey Staff, 1972-2006). It is characterized by a slope of 0-1% with soil 600 – 1200 m in depth. Dc13 is dominated by 57% Valsrivier with a depth of greater than 1200 mm, 15% Bonhein, 10% Arcadia and others at low percentages per surface area. The A horizon has a range of 20-30 % clay content with the B horizon 45-60% clay content for Valsrivier, while Bonhein has 35-45% clay content in the topsoil and a subsoil of 40-55% at 300-450 mm depth (Land Type Survey Staff, 1972-2006).



Map.1.1 The study area showing the Modder/Riet catchment map and the long-term rainfall across the catchment (*http://www.agis.za*)

c) Rainfall and temperature data

The annual and monthly rainfall pattern was analyzed for each station from the daily rainfall extracted from the ARC-ISCW databank and it was processed in MS Excel and using INSTAT+ software. Minimum and maximum temperature graphs were processed in Excel (refer to Appendix 1A Fig. 4).

d) Farming System Approach with Action Learning Cycle

The Action learning cycle, adopted from action research (Dick, 2002, Kemmis, & McTaggart, 2000, Reason & Bradburyn, 2001) allows an iterative and cyclic process during decision making for planning, action, observation and reflection stages. The theory is generated in the manner of understanding of what happened, when, how and why. When the situation is well understood, the information that emerges helps in planning for the next action with the aim of improving the situation and decisions made (Diagram 1 & 2).

The Farming Systems Approach (FSA) was adopted for the implementation of agrometeorology information in the south-western Free State FSA focuses on a holistic approach to emerging agricultural producers for adoption of sustainable agricultural principles. Biggs (1985) explained FSA concepts as an inter-disciplinary, participatory and bottom-up planning approach that aims at developing the farm household systems. FSA builds on the principles of improving productivity, increasing profitability, stability and ensuring sustainability (Biggs, 1985; Simmonds, 1985).

This approach was selected amongst others because it involves working directly with the farmers (FAO, 1990, Friedrich, *et al.,* 1994, Smith, 2006). FSA is a soft system approach where boundaries are demarcated and the situation for concern is discussed with the actors (Matata *et al.*, 2001, Mloza-Banda, 2005). Initially, FSA was chosen as the main methodology for this research study, but through evolution of my own theories and practice, the study approach and then later this thesis research were firmly placed under the umbrella of action research. This influence and complementation of FSA with action research principles resulted in a much improved research framework and process, which led to the improvement of all major phases.

An action learning cycle was concurrently used during the FSA planning phase since it is learning from concrete experience, thorough group discussion, discovery and learning from each other (Taylor *et al.*, 1997). The actions taken and experienced by the farmers were scrutinized to improve performance and get better adoption of weather forecasts and climate predictions (Kramer, 2007, Serrat, 2008; Gordon, 1993; Revans, 1982). Participants were encouraged to meet regularly with agrometeorologists and work collectively to solve problems faced on their farms (Tenge, 2005; Marquardt, 2004; Kolb, 1984). This combination of two participatory methods was used in this study to encourage, empower and teach farmers about the application of seasonal forecasting to agricultural decision-making.

Facilitating the application of agrometeorological information/advisories/services was made possible through the use of participatory action research methodologies, techniques and tools which guided participants to visualize, reflect and understand issues, to communicate with each other, analyze options and make research decisions in a structured way (Doherty & Hope, 2000; McNiff, 2002; Smith, 2006;). Participatory tools used to collect data were focus group discussion, key informants, informal interviews, transect walks, resource mapping, presentations, structured questionnaires, buzz questions, Venn diagram and stakeholder matrix. The methodologies were most appropriate for the nature of the study.

Activities followed to exchange information with the farmers for the dissemination and applications of agrometeorological information/advisories/services in the south-western Free State are mentioned below:

1. Identification of Extension Agents for assistance in selection of target groups in the south-western Free State.
2. Needs analysis in terms of agrometeorological services, methods of information dissemination and traditional knowledge on rainfall forecasting.
3. Obtain good understanding of weather forecasts and climate predictions and its application in agriculture.
4. Discussion with key informants and farm visits to identify the agricultural activities practiced by farmers.
5. Attendance at monthly meetings to disseminate and deliver advisories on alternative and adaptation practices according to weather/climate information/advisories/services.
6. Farmers implement their own plans on farm.
7. Invite key informants or experts in the field of agrometeorology to meetings.
8. Evaluation of the impact of a forecast, of dissemination methods and of updates of a forecast.

As exit strategy continuation of the development of tailor made advisories and dissemination of information training of intermediaries was conducted, suitable information dissemination methods were identified, provision of agrometeorological services to the target group is continued by ARC-ISCW;

Diagram 1. Development, dissemination and implementation strategy with incorporation of participatory tools.

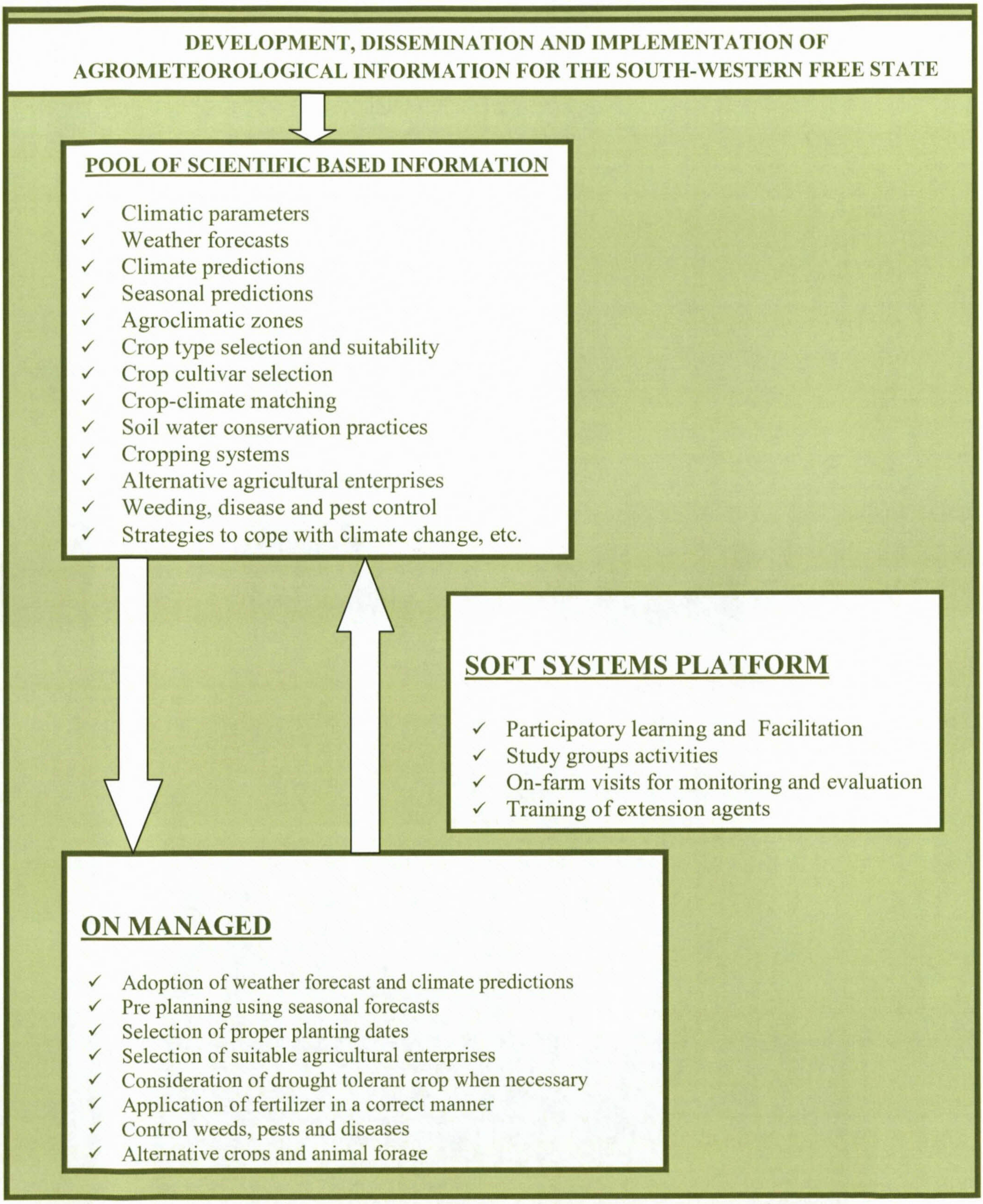
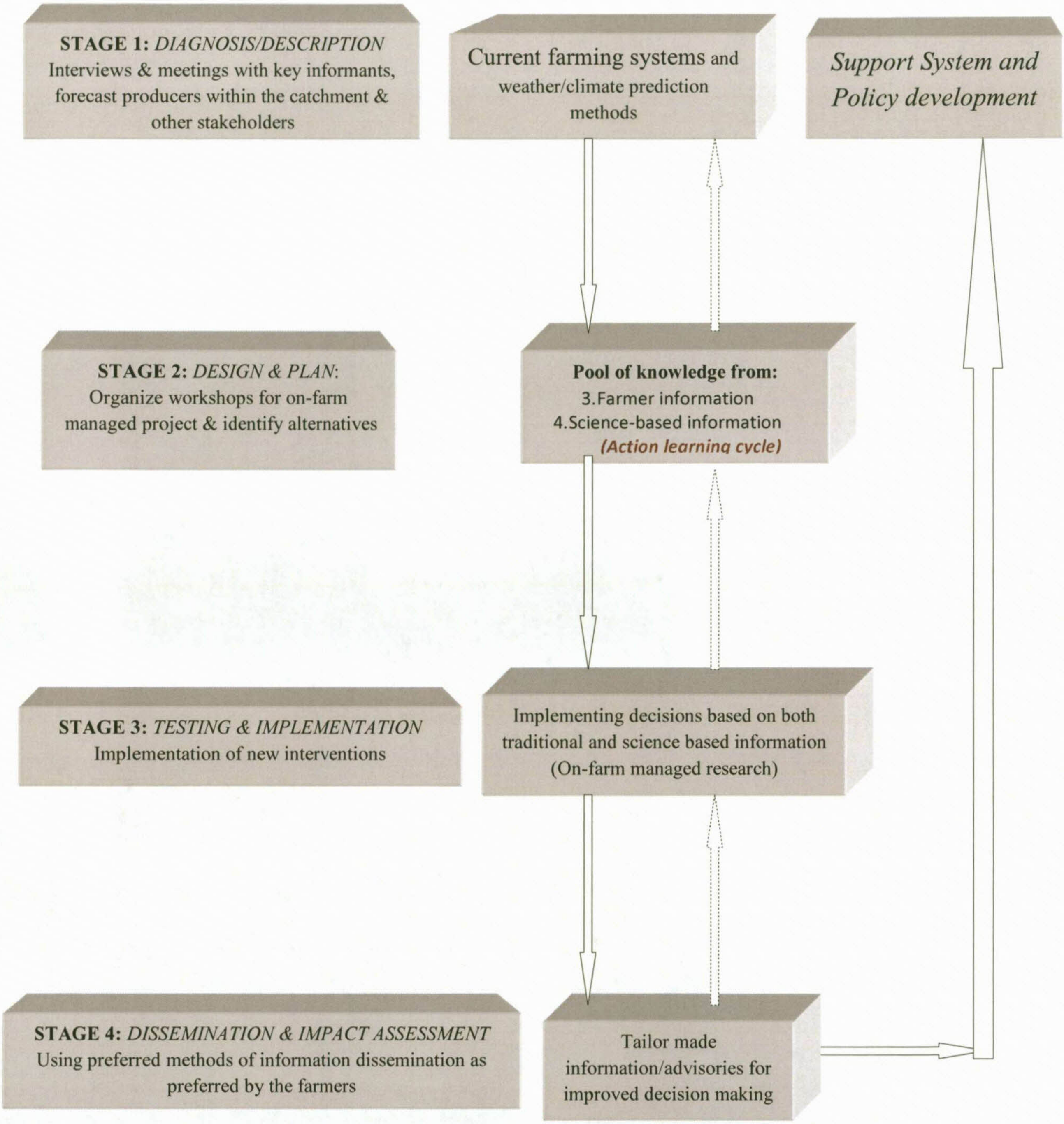


Diagram 2: An illustration of the research process used in south-western Free State for the adoption of climate/weather information and service/advisories in crop and animal production and agroforestry. (Also appear in Chapter 1).



The objectives of the project were achieved by implementing an iterative action learning cycle within the following stages of the Farming Systems; also appear in Chapter 1 (Diagram 2).

v. **Diagnosis/Description** of farmers' needs in relation to the agrometeorological information/advisories/services using diagnostic surveys, including relevant qualitative and participatory methods. Identify typologies within the farming community and among stakeholders relevant to the system.

vi. **Design Planning** of the scenarios per agricultural enterprise through the use of participatory tools and techniques such as workshops, focus groups, key informants, formal and informal interviews, action planning, look and learn, role-play, learn by doing, observations and transect walks.

vii. **Testing and Implementation** through farmer-managed experiments according to planned interventions and activities. Provision of agrometeorological advisories/services with detailed agrometeorological information, such as sowing dates, crop cultivars, soil water capacity, irrigation scheduling, rainfall probabilities, etc.

viii. **Dissemination and impact assessment** using dissemination methods as preferred by the farmers, for example bulk SMS, monthly meetings, on-farm visits and internet. Strategies that would be identified and screened during the planning and testing of implementation stages are sent to the users of information. This stage facilitates the dissemination and impact assessment by the monitoring and evaluation of the adoption of science-based weather/climate information and advisories/services and its impacts. At this stage, future priorities could be developed based on the weather/climate information predicted.

The selection of this illustration (Diagram 1) of the research process was used in the south-western Free State, integrates the action learning cycle (plan-act-observe-reflect) in stage 2 (Design & Planning) of the FSA. These approaches were used concurrently to promote the use of climate/weather information and services/advisories in crop and animal production and agroforestry to interact and exchange information with the farmers.

e) Decision tree analysis refer to Appendix 1.3

A decision tree (DT) uses a tree-like diagram (Yang, 2006; Hardaker *et al.*, 2004) to choose between various courses of action (Olivas, 2007) or to explain and divide choices or alternatives for a specific activity. DTs are a method to help one to make good choices when high risk decision must be taken, which uses a diagramme approach to compare competing alternatives (Olivas, 2007). They provide effective structure to explore different options for the investigation of a range of possible outcomes (Cha & Tappert, 2009). They provide a balanced structure of risks and rewards related to possible course of action. They articulate strategies for a given kind of an environment for the development of alternative choices or decision scenarios (Papagelis & Kalles, 2001; Yi-yang, & Nan-ping, 2009;

Waheed *et al.,* 2006). They can also be used to supplement other strategic planning and participatory tools and techniques. The decision tree analysis for this study is used to explore together with the farmers strategic farm management options under the whole range of weather/climate conditions. This analysis was selected so as to choose the most suitable option when considering the alternative interventions or agricultural activities under the current weather/climate conditions and according to the forecast.

A decision tree used to articulate strategies for a given kind of an environment for the development of alternative choices or decision scenarios (Papagelis & Kalles, 2001; Yi-yang, & Nan-ping, 2009; Waheed *et al.,* 2006). They can also be used to supplement other strategic planning and participatory tools and techniques (Appendix 1.13).

f) Dry spell probabilities

The long term rainfall data for Glen Agricultural Research Experimental site at longitude -28°92"08', latitude 26°35"94' and at 1344m altitude was used to calculate dry spell probabilities. The long-term daily rainfall dataset of 57 years from 1950-2007 for Glen Agricultural College weather station was analyzed for dry spells during the summer rainfall season. The probabilities of dry spells were developed starting from September until March, which is the main summer growing season and precipitation period in the south-western Free State. The Instat+ statistical package was used to calculate the occurrence of dry spells of more than 7, 10 and 15 days using a 0.85 mm per day threshold as described by Stern *et al.* (1982).

g) Crop selection

Ehlers crop suitability zones were developed to specify the suitability of crops and their adaptability to the environment (Ehlers, 1988). Crops are divided into zones according to the plant temperature requirements. The zones are identified by four digits, the first two digits represent the average temperature for summer months and the last two digits represent the winter months day and night average temperatures. The conditions are given as optimal (crops well suited for a specified environment), sub-optimal (crops that can grow in a specified environment with consideration of controlling the climate conditions) and marginal (crops that are not adaptable to a specified environment). Undifferentiated means that the crop's adaptability to the zone has not been researched and defined.

Ecocrop2 was designed by FAO (FAO, 2004). It is an environmental response database, designed on crop responses in relation to environmental management factors. This database requires the environmental information such as climatic conditions, plant types and soil factors. Ecocrop2 is used to identify suitable crops for a specified environment, for a defined use and it has a library of crop environmental requirements. It identifies plant species with key climate and soil requirements that match the data entered into the software. When all information as specified has been entered into the system, it gives a list of crops suitable for the specified environment.

h) Eco Crop 2

Ecocrop2 is a web-based system (online system) and a module developed by the FAO to list crops for a prescribed set of climate and soil data (FAO, 2004). This module contains information for more than 2568 crops. The parameter definitions are comprehensive but simple and could easily be attached within the accessible database. Ecocrop2 runs on a CD and also available on the internet. The Ecocrop 2 crop selection model was selected due to its large number of crops available in the system and its suitability requirements. It is also chosen as crop requirement database for crop selection. Ecocrop2 tasks are to identify suitable plants for a specified environment, identify plants for a defined use and lastly identify plants for a defined description (*http://ecocrop.fao.org*). Ecocrop 2 defines crops according to temperature, rainfall, light requirements, soil texture, depth, drainage, pH, salinity and fertility. It is a trusted and advanced crop model as it gives attention to detail on climate and soil requirements (*http://www.agis.za)*.

The Ecocrop2 database uses five temperature thresholds, that is killing, minimum, optimum minimum, optimum maximum and maximum temperature The cardinal or threshold temperatures are the minimum, below which there is insufficient heat for biological activity, the optimum range, at which the rates of metabolic processes are at their maximum, and the maximum beyond which growth ceases (Tivy, 1990; Arnon, 1992). The killing or detrimental temperature is defined as the single event that would severely damage the whole crop plantation. For example, overnight under extremely low temperature a one hectare field of potatoes or tomatoes and other frost sensitive crops can be severely damaged and destroyed. This could result in noticeable financial loss to farmers.

APPENDIX 1.1 What is agrometeorology?

It deals with the influence of weather and climate to agriculture or we can say it deals with weather-sensitive fundamentals of agriculture production. Farming is dependent on weather and climatic conditions. Farmers can be faced with hazards, loss of livestock, crop production lessens or damaged houses and animal shelters destroyed, and thus lead to economic growth weakens, food insecurity and poverty strife.

Importance of using weather forecasts and climate predictions:

- ✓ To develop conducive coping strategies according to the seasonal predictions
- ✓ To produce for consumption and income generation
- ✓ To use land effectively and efficiently
- ✓ To learn the strategies for adaptation
- ✓ To understand the concept of Soil-Plant-Atmospheric continuum

For example,

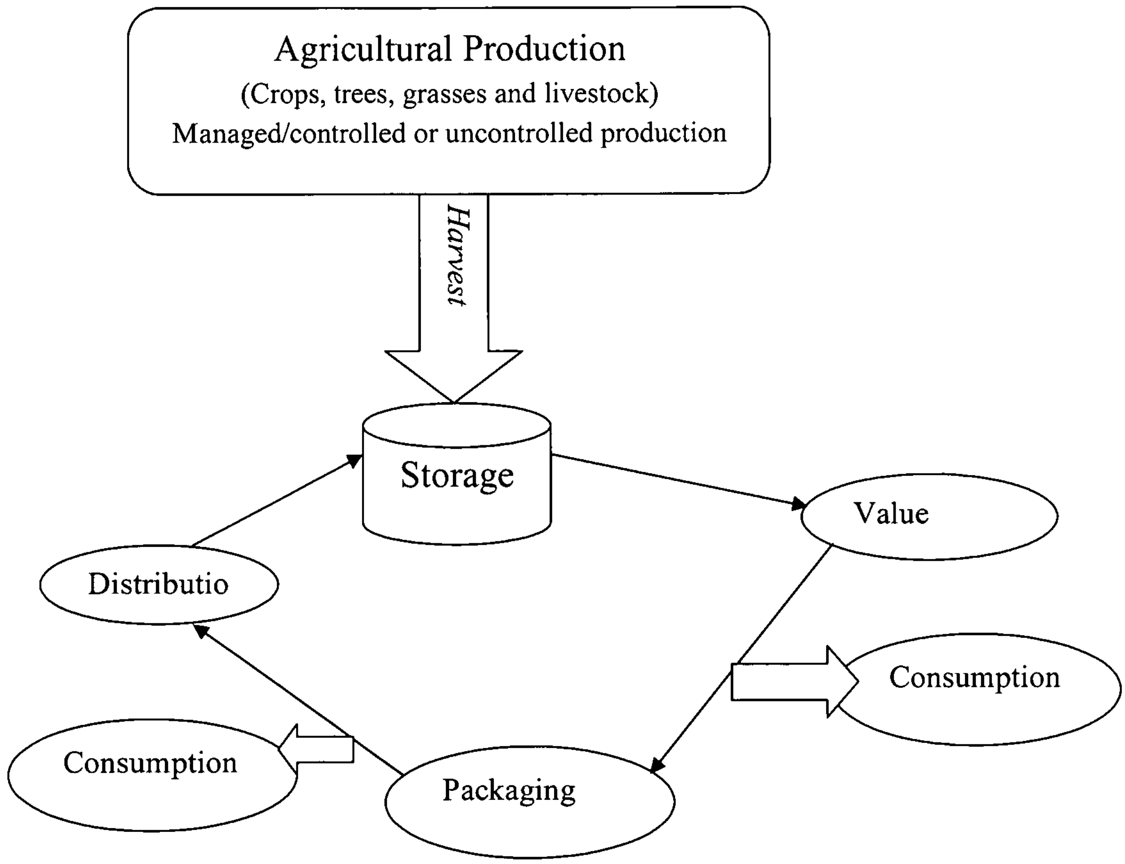


Fig. 1 Agricultural production chain from production to value adding to consumption where weather-sensitive elements are dealt with.

Adaptation strategies for crop and animal production

Weather forecasts are crucial in all farming operations, for example under crop production Land cultivation, For planting, Transplanting, Weeding, Mulching, Irrigating, Spraying, Harvesting

For example under animal production

Site selection: for housing to minimize the effects of local weather and to proper select a site to emphasize factors for enhanced heat dissipation (minimal radiation, air temperature and humidity, maximal air velocity) for long term protection benefits.

Windbreaks: for shelter from strong winds and cold weather. Structures and trees can reduce wind speed and are beneficial to survival of exposed animals most especially calves. Windbreak acts as a barrier that lowers the wind speed near the ground surface and diverts and splits the air stream.

Shades: is used for protecting farm animals in hot climates. When dairy cows are given access to adequate shades, milk production is increased. Trees can be used as shades to provide protection from sunlight, combined with beneficial cooling as moisture evaporates from the leaves. De-horning

Rainfall characterization of importance to farming production

- ✓ Rainfall
  - Rainfall onset
  - Rainfall distribution
  - Wet/dry spells probability
  - Rainfall cessation
- ✓ Temperature
  - Winter/summer seasons
  - Onset of first frost and last day of frost
  - Wind chill
  - Heat waves and Heat units (cultivar selection)
- ✓ Types of forecasts available from South African Weather Services
  - 0-6 hour (now casting)
  - Daily
  - 7 day (weekly)
  - 14 day
  - Monthly
  - Seasonal (3 months) and 3-6 months

The seasonal forecasts are received a month before the season for pre-planning on agricultural activities. It is advisable to use this forecast together with the short-term forecast such as daily or weekly which is also available a week or two in advance for proper planning of tactical and operational activities.

APPENDIX 1.2 Principles of pest and disease management

Farming activities need to be matched with a good plan on weed, pests and disease management Good quality crop production is the outcome of well-developed coping strategies by using weather forecasting and climate predictions. Farmer need to develop the economic and reliable strategy of weed controlling, defense against pests, suitable crop and cultivar selection, suitable site or field selection, land preparation, planting methods, planting dates, cropping systems, irrigation scheduling, and fertilizer application.

For example:

Site or field selection: For crop production the land should be well-suited for the crop. Soil profile must be characterized to ensure that there is sufficient depth, uniform in texture and nutrient content and through soil analysis tests the farmers will be able to determine the soil status and be able to purchase the required fertilizer.

Land preparation: the planting sites and fields that are well-prepared turns to have better plant development and growth. The soil should be cultivated at a considerable dry condition. The soil should not be worked when it is too wet or else this action results to muddy and compaction conditions. During heavy rains, ridges should be established to give provision of water flow and to minimize the chances of water logging.

Crop selection: Different climatic conditions and soil types are suitable for different crop types. For example, Free State province in known to be the bread basket of South Africa because of its capability to produce most grain crops throughout the country. Suitable crop selection leads to better crop growth and improved crop production.

Cultivar selection: It is always advisable to select high performing cultivar for any type of crop selected for improved production. Depending on the weather forecasts and seasonal predictions it should be easier to match cultivars with weather forecasts. For example, bolting resistance cultivars for Swiss chard producers is a recommendable option since it can be harvested for at least a period of 3 years in the Free State. Under dry predicted conditions heat tolerant varieties for vegetables such as cabbage, lettuce and peppers are critical. Under heavy rains it is recommended to avoid crops sensitive to water logging.

Planting dates: Proper selection of plant dates can lead to better crop growth and production. This can also avoid the spread of certain weeds, insects and diseases since such are prone to manifest at a particular time of the year and when conditions are conducive. Planting dates must be selected to allow the crop to reach its optimal maturity. Planting few days prior the onset of rains is a better option. Depending to the seasonal forecasts the farmer can choose to plant late or early in the season. Sequential or staggering cropping can be possible for continuous crop production. Fertilizer application should be according to the recommendations made from soil analysis to balance nutrients throughout the growing season. Irrigation scheduling is necessary to avoid water stress most especially during crop sensitive stages to avoid the consequences of water stress and drying out of crops prior maturity stages. Supplementary irrigation can be applied where possible according to the water crop requirement. Different types of irrigation methods can be used.

APPENDIX 1.3 What is drought?

Drought is the effect of a natural decline in the amount of rainfall received over an extended period of time such as season or more in length.

Drought severity is dependent not only on:

- ✓ the duration,
- ✓ intensity, and
- ✓ geographical extent of the specified drought episode

There are different types of drought

- ✓ **Meteorological drought** – expressed solely on the basis of dry variation from some normal of rainfall.
- ✓ **Agricultural drought** – linking various aspects of meteorological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits and so forth. An operational definition of drought should take into account the variable susceptibility of crops at their different stages of development.
- ✓ **Hydrological Drought** – concerned with the shortfalls in water supply rather than precipitation. These droughts usually lag behind and are out of phase with meteorological and agricultural drought. Competition for stored water resources escalates during a hydrological drought. This type of drought is often defined at river basin scale. Hydrological drought may exist downstream from the area of meteorological drought (i.e. in a completely different region).
- ✓ **Socio-economic drought** – exists when there is a shortfall in the supply of some service related to the elements of meteorological, agricultural and hydrological drought. There has been the suggestion that the time and space processes of supply and demand are two basic processes that need to be included in an objective definition of drought.

APPENDIX 1.4 Frost Probabilities for Glen, Bloemfontein & Lady Brandt

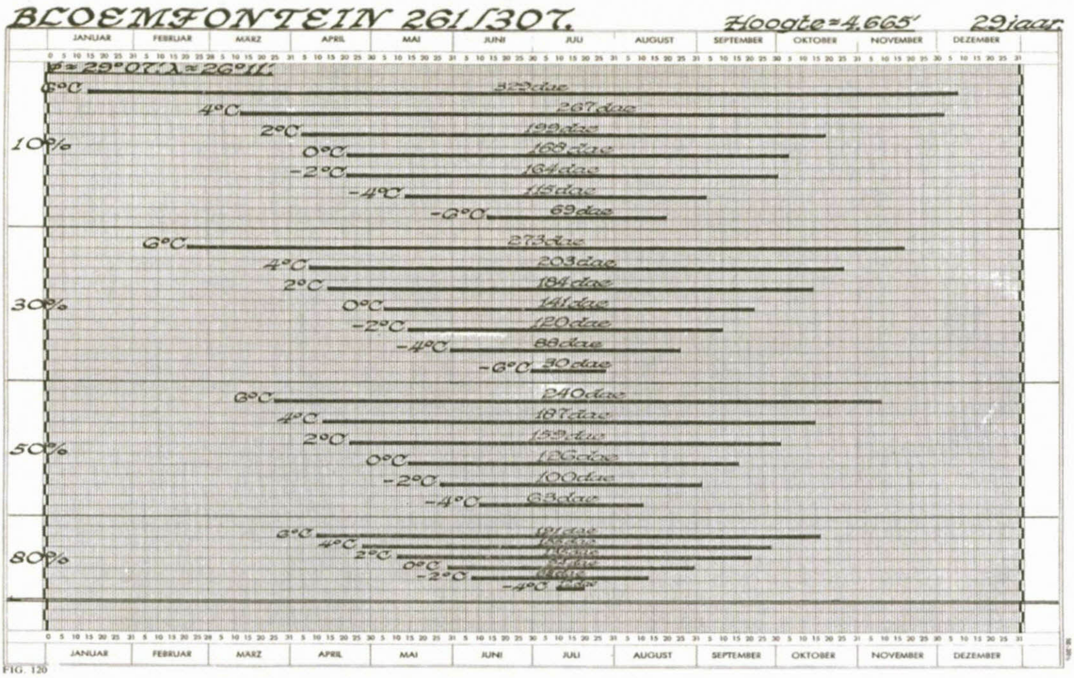


FIG. 120

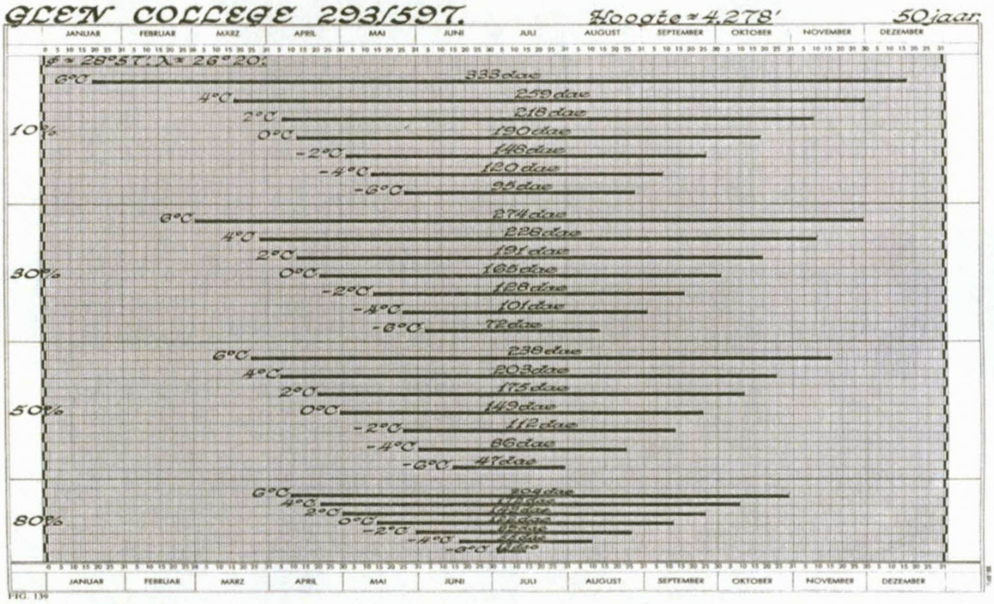


FIG. 139

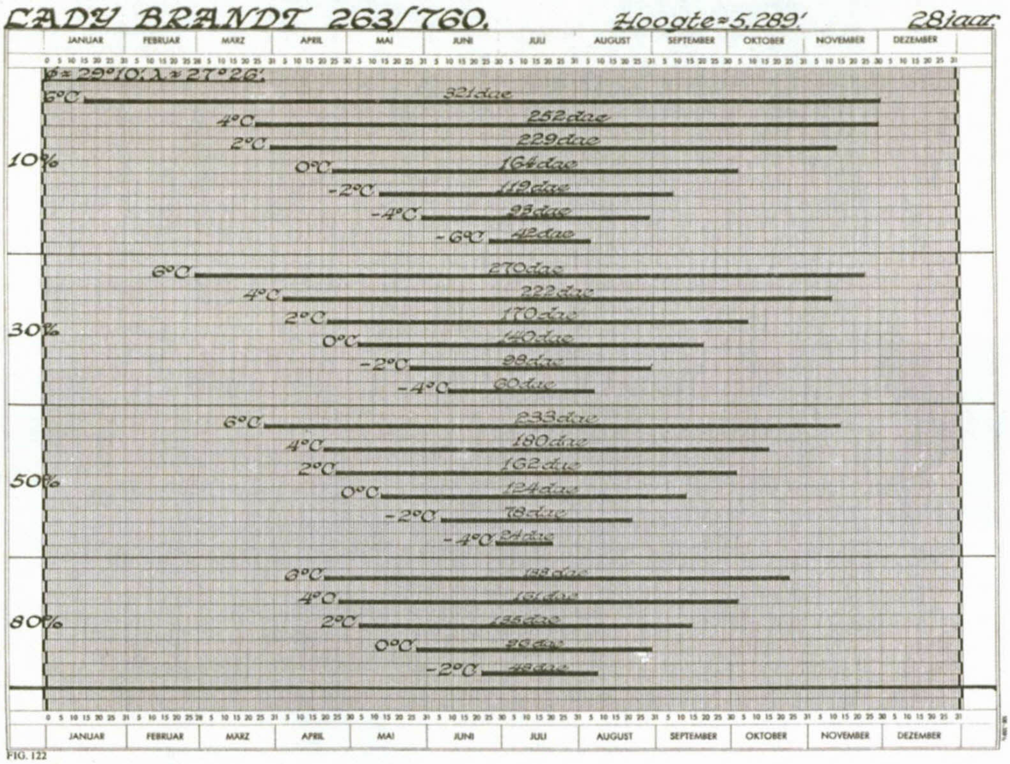


FIG. 122

Frost date (derived from above charts)	Glen	Bloemfontein	Lady Brandt
First frost date	15 April	21 April	24 April
Last frost date	19 October	5 October	4 October
Possible 1st planting date	November	November / December	November

Crop-climate matching

Using:

✓ FROST Tables for frost free selection date (Kotzé, 1980)

The long-term rainfall and mean temperature can be used to calculate the heat units with the following assumptions for example, planting dates for maize production in three different locations Glen, Bloemfontein and Lady Brandt, with the following assumptions:

- All months are 30 days
- Growing season = 120 days
- Tb (base temperature) of maize = 10 ° C
- Plant in season with highest rainfall amount
- Best yield will be obtained with highest thermal temperatures or degree days
- -2 °C and 10% probability frost options

- To select best location and planting date
  - for towns within the catchment

APPENDIX 1.5 Potato Production in the south-western Free State


Potato (*Solanum tubersome*) is sensitive to soil water deficits. Successful potato production is to a large extent dependent on the quality of the planting material (quality of seeds). Due to the susceptibility of the potato to several transmissible diseases, it is advisable not to multiply the same seed source for an indefinite period of time.

Water deficits have greatest adverse effect on yield during:

- ✓ The period of stolonization
- ✓ Tuber initiation and
- ✓ Yield formation,
- ✓ Whereas, during ripening and early vegetation are less sensitive.

- While 89% of the crop is under irrigation, 11% is cultivated under dry-land conditions.
- While 58% of the total crop consists of seed potatoes, 42% are table potatoes.
- There are two potato plantings, an early crop, planted from August to October, and a main crop planted from November to early February.
- The early crop is marketed from December to March and the main crop from April to October.

The main cultivars are:

- ➢ Table - Mondial, UTD and Sifra
- ➢ Seed – Mondial, Sifra and Fabula

To maximise yield soil water content should be maintained relatively high within the optimum value of 15-18°C for tuber formation. Furrow or sprinkle irrigation is recommended. Tuber growth is inhibited when below 10°C and above 30°C.

Potatoes are grouped into three varieties:

- ✓ Early (90-120days)
- ✓ Medium (120-150 days)
- ✓ Late varieties (150-180 days)

Late varieties produce good yields under both long and short day conditions

Potato should be grown in a 3 or more year rotation with crops such as maize.

APPENDIX 1.6 Farmer questionnaire conducted in 2008/09

ARC • LNR

Questionnaire: Farmers

Additional questionnaire on communication and use of weather/climate forecasts/predictions and other weather/climate advisories for comparison with an earlier similar one.

GENERAL INFORMATION:

Name of Interviewee: ....

Name of Farmer: ....

Farm Name: .... **Municipality:** ....

Province: ***Free Sate Province*** **Date:** ....

Gender of the farmer:

Female	**1**	**Male**	**2**

Status of the farmer:

Single/never married	1	Married	2	Divorced	3	Widow/ widower	4

3. Age of the farmer (in years): .... 4. Household size: ....

5. Farmer's educational background:

EDUCATIONAL LEVEL	*CODE*
▶ No educational training	1
▶ Less than standard 4 (<Grade 6)	2
▶ Standard 4-6 (Grade 6-8)	3
▶ Standard 7-8 (Grade 8-10)	4
▶ Standard 9-10 (Grade 11-12)	5
▶ Post matric	6

6. Are you a full-time farmer?

Yes	1
No	2

7. If 'No' to question 6, what is he/she doing except farming (occupation apart from farming)?

Teacher	1	Doctor/Nurse	2
Taxi driver/owner	3	Security guard	4

Tuck-shop owner	5	Domestic worker	6
Police man/woman	7	Traditional doctor	8
Headman (shepherd)	9	Other *(specify)*	10

8. What agricultural enterprises are you involved in?

a) Crops
b) Livestock
c) Mixed farming
d) Other: Specify: ....

1
2
3
4

9. Specify the types of crops you farm with.

....

10. What is the size of your farm? ....

11. How many ha are allocated for crop production? ....

12. What is your turnover in Rands per year?

....

13. Do you receive any seasonal climate predictions and if so how often during the growing season?

....

14. Through which media do you receive their seasonal /climate predictions?

....

15. How do you use these seasonal climate predictions?

....

16. Are you able to understand and interpret such predictions?

....

17. (a) How much value do you put on seasonal/climate predictions?

....

....

17 (b) What other weather/climate information and advisories do you make use of?

....

....

17 (c) How much value do you put on these other weather/climate information and advisories?..

....

18. (a) How reliable do you think the seasonal/climate predictions is for you?

....

....

18. (b) How reliable do you think the other weather/climate information (please specify this for each other weather/climate information and advisories you used)

....

....

19. What is the meaning of normal, below-normal and above-normal?

....

....

20. In your own words, what do you understand about, 30%, 60% and 80% probability of rainfall?

....

....

21. (a) Are you able to use the seasonal climate in planning your farm activities?

....

....

21. (b) Are you able to use other weather/climate information and advisories?

....

....

22. If above normal rainfall is predicted, what kind of adjustments do you make?

....

....

23. If a drought is predicted, do you make any adjustments to your activities?

....

....

24. (a) Do you make deliberate efforts to obtain climate prediction information?

....

....

24. (b) Do you make deliberate effort to obtain other weather/climate information and advisories? (Please specify)

....

....

25. (a) Would you consider paying for seasonal climate predictions?

....

....

25. (b) Would you consider paying for any other weather/climate information and advisories? (Please specify)

....

....

26. From which institutions or organizations do you receive other weather/climate information from and advisories than the seasonal climate predictions?

....

....

27. Should weather/climate information and advisories be made available to you, which method(s) of information transfer would you prefer?

....

....

28. How often do you have meetings with the local extension officers?

....

....

29. Do you receive any weather/climate related information and advisories from your extension officers?

....

....

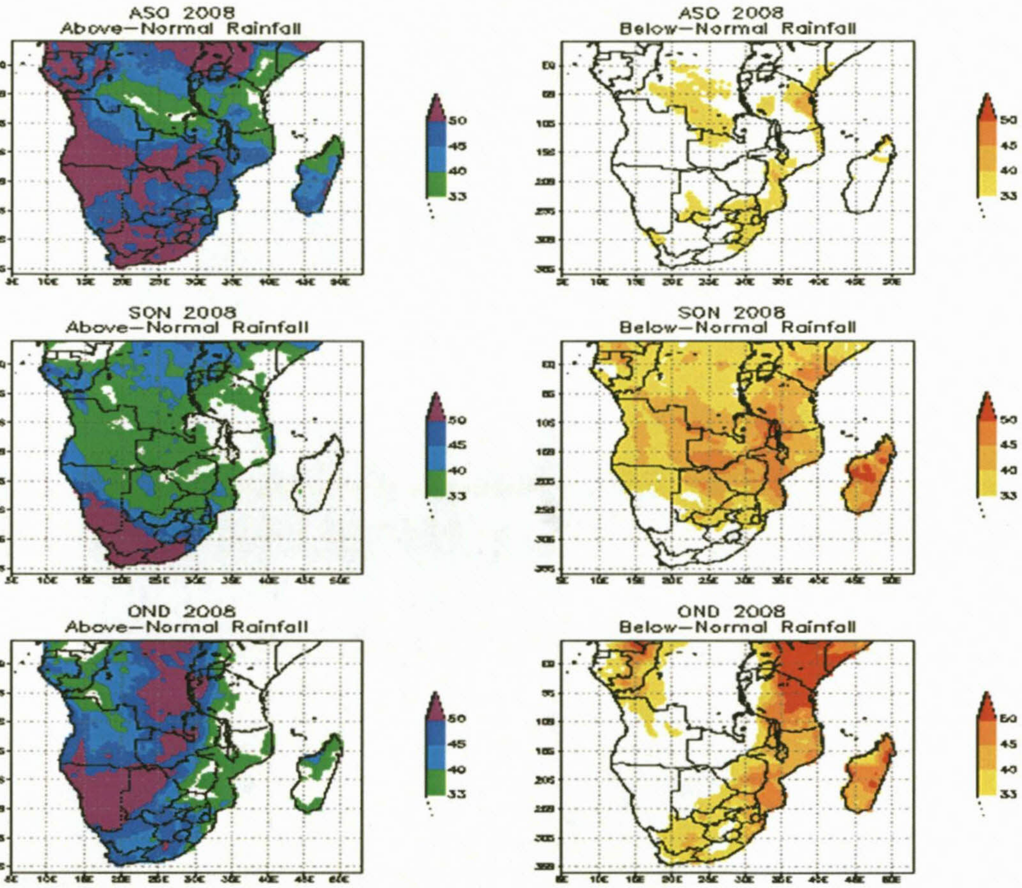
The Agricultural Research Council and the University of the Free State would like to thank the entire participant for making time to participate in our workshops and completing the questionnaire.

Thank you very much!!!!!!

APPENDIX 1.7 Examples of agrometeorological products sent to famers

(a)Seasonal advisory for south-western Free State for 2008

- ✓ August-September-October 45 – 50% for above normal rainfall and 33% for below normal,
- ✓ September-October-November 40-45% for above normal and below 33% for below-normal,
- ✓ October-November-December 45% for above normal and 33% for below normal
- ✓ Good chances of receiving good rainfall for the season.



Therefore:

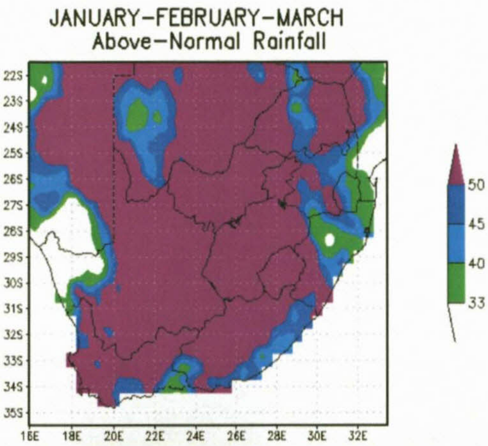
1. Farmers with access to water for irrigation can consider early planting for vegetables
2. It is advisable for rainfed farmers to plant few days before onset of rainfall.
3. Maize producers can consider to plant from 15th November 2008, 30 November 2008, 15 to late December 2008 and before 10 January 2009.
    a. Ensure that you plant the number of ha according to your budget
    b. Prepare before time for engaging into the field
    c. Order or buy seedling or seeds in advance
    d. Buy enough required amount of fertilizers as per advice provided from soil analysis
    e. Plant according to recommended planting dates
    f. Plant population can be increased since above-normal rainfall is predicted
    g. Control weeds

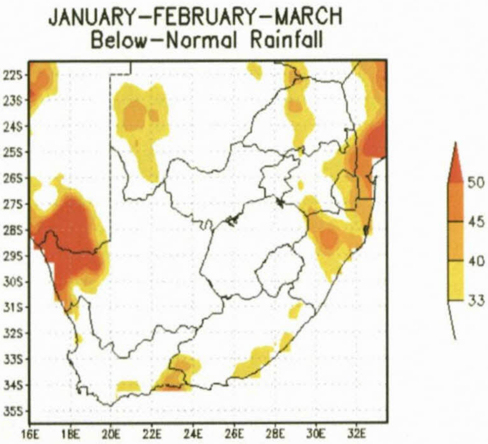
h. Follow the weather forecast throughout the growing season before engaging to any field or agricultural practices.

(b)Agrometeorological Advisory for South-western Free State (January 2013)

Seasonal Forecast Issued 22 November 2012 for January-February-March indicated the following:

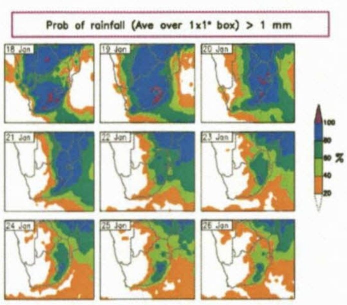
- ✓ Probabilities for above-normal rainfall are expected south-western Free State and most parts of the Province (SAWS).

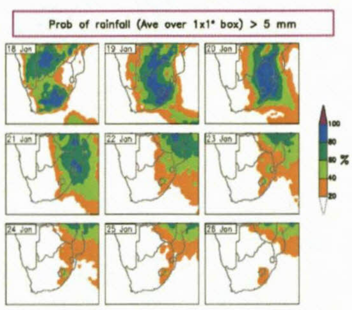


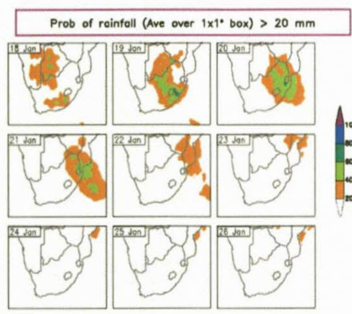


14-day forecast Issued 13 January 2013by SAWS.

- ✓ Approximately 80% chances that the rains will occur in places of the Free State
- ✓ Possibilities for flooding are expected







Advisory for livestock producers:

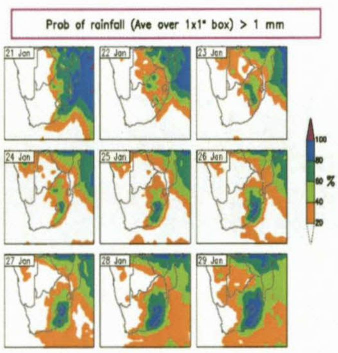
- ✓ In occurrence of flooding, farmers located closer to the river should consider re-locate livestock or avoid livestock grazing along river banks
- ✓ Provide safe shelter and feed for livestock
- ✓ Cover urea licks with plastic
- ✓ Ensure animal are vaccinated to prevent possible outbreak of diseases

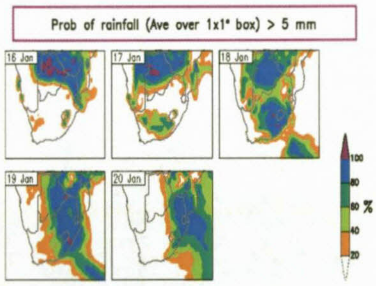
For crop producers:

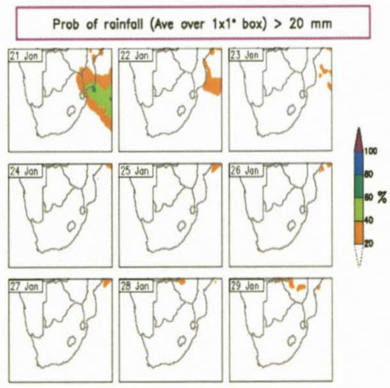
- ✓ Spraying herbicides and insecticides is not a good idea when heavy rains area predicted
- ✓ No fertilizer application when heavy rains are predicted
- ✓ No irrigation to avoid water logging
- ✓ picking of vegetables for the market and weeding is not advisable due to muddy conditions
- ✓ When heavy rains have subsided check the field for there is a possibility of pests and disease outbreaks which may be triggered by high relative humidity or high moisture content
- ✓ In case of outbreak of pests of diseases see below the forecast to select the suitable day for spraying

It is advisable to continuously check the daily forecast for proper planning of agricultural activities.

See below:14 day forecast for the following week







APPENDIX 1.8 Beef management advisory distributed in 2009

Summer season livestock may suffer from heat stress which:

- Lowers productive and reproductive efficiency in farm animals
- Improve comfort productivity (dietary increase proteins and amino acid)
- Heat losses (radiation, conduction and convection) and body air temperature↑
- Feed intake is inhibited and
- Production decreases

Special Precautions

- Good quality dietary nutrients
- Shelters
- Trees for shade
- Access to good quality water.

Information is the best tool against poor production.

APPENDIX 1.9 Extension agent questionnaire prior workshops

ARC • LNR

Extension Officer Questionnaire May 2012

(prior workshop)

Communication and use of weather/climate forecasts/predictions and other weather/climate advisories with focus to the use of science based and traditional forecasts/predictions and advisories.

General Information:

Name of Participants ....

Male/Female ....

Age of participant..

Highest Qualifications..

Field of Operation..

District and Local Municipality..

Region/ward of Responsibility..

Number of Farmers at your region/ward..

1. Farming systems at your ward ....

Crops	Livestock	Trees

Other (please specify) ....

2. What is the range of size of the farms you working at, are there any subsistence farmers, commercial farmers and/or resource poor farmer?

....

3. Do you receive any seasonal climate predictions and if so how often before (lead time), during and after the growing season? (Please specify, how do you use it with the farmers)

....

4. From which organization/s do you receive weather forecasting/climate predictions and science based weather/climate information?

....

5. Through which media do you receive these weather/climate forecasting/predictions and weather/climate advisories?

....

6. Do you receive any traditional weather/climate forecasts/predictions and if so how often before (lead time), during and after the growing season? (Please specify)

....

7. How do you use these weather/climate forecasting/predictions and weather/climate advisories with the farmers?

....

8. How do you use these traditional weather/climate forecasting/predictions and traditional advisories?

....

9. Are you able to understand and interpret weather/climate forecasting/predictions and science-based advisories?

....

10. Are you able to understand and interpret traditional weather/climate forecasting / predictions and traditional advisories?

....

11. How much value do you put on these seasonal climate predictions?

....

12. What other science based weather/climate information and advisories (for example weather forecasts, early warnings of drought, frost, hail and/or heavy wind etc.) do you make use of? (Please specify how do you use it with the farmers)

....

....

13. What traditional climate predictions do you make use of? (Please specify how do you use it with the farmers)

....

....

14. How much value do you put on these traditional climate predictions (Please specify)

....

15. How much value do you put on this traditional weather/climate information (Please specify how your farmers make use of)

……………………………………………………………………………………………

16. (a) How reliable do you think the seasonal climate predictions are for you and your farmers?

……………………………………………………………………………………………

16. (b) How reliable do you think the traditional climate predictions are for you and your farmers?

……………………………………………………………………………………………

17. What is the meaning of normal, below-normal and above-normal?

……………………………………………………………………………………………

18. In your own words, what do you understand about 30%, 60% and 80% probability of rainfall?……………………………………………………………………………………

19. (a) Are you able to use the seasonal climate predictions in planning with your farmers for their farm activities?

……………………………………………………………………………………………..

19 (b) Are you able to use traditional climate predictions and/or other traditional weather/climate information and advisories in any way?

……………………………………………………………………………………………

20. If above normal rainfall is predicted, what kind of recommendations do you make with your farmers?

……………………………………………………………………………………………

21. If a drought is predicted, do you make any recommendations to your farmers' activities?

……………………………………………………………………………………………

22. (a) Do you make deliberate efforts to obtain climate prediction information?

……………………………………………………………………………………………

22. (b) Do you make deliberate effort to obtain other science based weather/climate information and advisories to advise your farmers to make necessary adjustments?

……………………………………………………………………………………………

22 (c) Do you make deliberate effort to obtain traditional climate predictions and/or other weather/climate information and advisories to advise your farmers to make necessary adjustments?

……………………………………………………………………………………………

23. (a) Do you think your Provincial Department of Agriculture Forest and Fisheries would consider paying for seasonal climate predictions, science based weather/climate and advisories?

……………………………………………………………………………………………

23. (b) Do you think your Provincial Department of Agriculture Forest and Fisheries would consider paying for any traditional climate predictions and/or other traditional weather/climate information and advisories? ....

4. (a) Should climate predictions be made available to you for the good quality use of the farmers which method(s)/channel(s) of information transfer would you prefer?

....

4. (b). Should other science based weather/climate information and advisories be made available to you, which method(s)/channel(s) of information transfer would you prefer?

....

25. How often do you have meetings with the farmers at the area of your responsibility?

....

26. Currently, do you receive any climate predictions and/or science based weather/climate related information and advisories to your farmers?

....

27. Currently, do you receive any traditional climate predictions and/or other weather/climate related information and advisories from to your farmers?

....

APPENDIX 1.10 Extension agent questionnaires after workshops

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UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS·UV
NATURAL AND AGRICULTURAL SCIENCES
NATUUR- EN LANDBOUWETENSKAPPE

Extension Officer Questionnaire May 2012

Communication and use of weather/climate forecasts/predictions and other weather/climate advisories with focus to the use of sciences based and traditional forecasts/predictions and advisories.

General Information:

Name of Participants ....

Male/Female ....

Age of participant...

Highest Qualifications..

Field of Operation...

District and Local Municipality..

Region/ward of Responsibility..

Number of Farmers at your region/ward...

1. Not Satisfactory, 2. Satisfactory, 3. Good, 4. Excellent

Questions	*Grading*
1. How would you grade today's workshop?	
2. Would you encourage more of agrometeorological information days?	
3. Was the information presented of benefit to your daily work as an extension officer?	
4. Do you think your farmers will benefit from agrometeorological information?	
5. Do you think accessibility to this type of information, could improve farming production?	
6. Do you think information presented was well prepared?	
7.	

ANY COMMENTS:

____

____

APPENDIX 1.11 Farmer questionnaires distributed in April 2012

Questionnaire: Farmers

Additional questionnaire on communication and use of weather/climate forecasts/predictions and other weather/climate advisories for comparison with an earlier similar one. This time we added questions on communication and use of traditional forecasts/predictions and other traditional weather/climate information and advisories.

GENERAL INFORMATION:

Name of Interviewee: ....

Name of Farmer: ....

Farm Name: .... **Municipality:** ....

Province: ***Free State Province*** **Date:** ....***District***

1. Gender of the farmer:

Female	1	Male	2

2. Status of the farmer:

Single/never married	1	Married	2	Divorced	3	Widow/ widower	4

3. Age of the farmer (in years): ....

4. Household size: ....

5. Farmer's educational background:

EDUCATIONAL LEVEL	*CODE*
► No educational training	1
► Less than standard 4 (<Grade 6)	2
► Standard 4-6 (Grade 6-8)	3
► Standard 7-8 (Grade 8-10)	4
► Standard 9-10 (Grade 11-12)	5
► Post matric	6

6. Are you a full-time farmer?

Yes	1
No	2

7. If 'No' to question 6, what is he/she doing except farming (occupation apart from farming)?

Teacher	1	Doctor/Nurse	2
Taxi driver/owner	3	Security guard	4

Tuck-shop owner	5	Domestic worker	6
Police man/woman	7	Traditional doctor	8
Headman (shepherd)	9	Other *(specify)*	10

8. What agricultural enterprises are you involved in?

e) Crops
f) Livestock
g) Mixed farming
h) Agroforestry
i) Other: Specify: ....

1
2
3
4

9. Specify the types of crops you farm with.

....

10. What is the size of your farm? ....

11.(a) How many ha are allocated for crop production? ....

11 (b) How many ha are allocated for grazing? ....

11 (c) How many ha are allocated for fruit trees or any other type of trees? ....

12. What is your turnover in Rands per year? ....

13. Do you receive any seasonal climate predictions and if so how often before, during and after the growing season? (Please specify)

....

14. Through which media do you receive these seasonal climate predictions? ....

15. How do you use these seasonal climate predictions? ....

16. Are you able to understand and interpret such predictions?

....

17. How much value do you put on these seasonal climate predictions?

....

18 What other science based weather/climate information and advisories (for example weather forecasts, early warnings of drought, frost, hail and/or heavy wind etc.) do you make use of? (Please specify)

....
....

19. How much value do you put on these other science based weather/climate information and advisories? (Please specify as above)

....
....

20. What traditional climate predictions do you make use of? (Please specify)

....

21. How much value do you put on these traditional climate predictions (Please specify)

....

....

22. What other traditional weather/climate information do you make use of (Please specify)

....

....

23. How much value do you put on this other traditional weather/climate information (Please specify)

....

24. (a) How reliable do you think the seasonal climate predictions are for you?

....

24 (b) How reliable do you think the traditional climate predictions are for you? (Please specify)

....

24. (c) How reliable do you think the other science based weather/climate information is for you (Please specify)

....

24. (d) How reliable do you think the other traditional weather/climate information is (Please specify)

....

....

25. What is the meaning of normal, below-normal and above-normal? ....

26. In your own words, what do you understand about 30%, 60% and 80% probability of rainfall?

....

....

27. (a) Are you able to use the seasonal climate predictions in planning your farm activities or in any other way?

....

27. (b) Are you able to use other science based weather/climate information and advisories in any way?

....

....

27 (c) Are you able to use traditional climate predictions and/or other traditional weather/climate information and advisories in any way?

....

....

28. If above normal rainfall is predicted, what kind of adjustments do you make?

....

....

29. If a drought is predicted, do you make any adjustments to your activities?

....

....

30.(a) Do you make deliberate efforts to obtain climate prediction information?

....

30. (b) Do you make deliberate effort to obtain other science based weather/climate information and advisories? (Please specify)

....

30 (c) Do you make deliberate effort to obtain traditional climate predictions and/or other weather/climate information and advisories? (Please specify)

....

....

31. (a) Would you consider paying for seasonal climate predictions?

....

....

31. (b) Would you consider paying for any other science based weather/climate information and advisories? (Please specify)

....

....

31 (c) Would you consider paying for any traditional climate predictions and/or other traditional weather/climate information and advisories? (Please specify)

....

....

32 (a) From which institutions or organizations do you receive other science based) weather/climate information and advisories than the seasonal climate predictions? (Please specify)

....

32 (b) From whom do you receive traditional climate predictions and other traditional weather/climate information? (Please specify)

....

33 (a) Should climate predictions be made available to you, which method(s)/channel(s) of information transfer would you prefer?

....

33 (b). Should other science based weather/climate information and advisories be made available to you, which method(s)/channel(s) of information transfer would you prefer?

....

34. How often do you have meetings with the local extension officers?

....

35 (a).Do you receive any climate predictions and/or science based weather/climate related information and advisories from your extension officers?

....

....

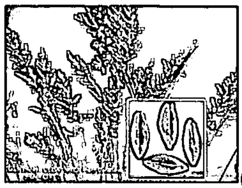
35 (b) Do you receive any traditional climate predictions and/or other weather/climate related information and advisories from your extension officers?

....

The Agricultural Research Council and the University of the Free State would like to thank all participants for making time to take part in our workshops and completing the questionnaire.

Thank you very much!!!!!!

APPENDIX 1.12 *Eragrostis Curvula* (Weeping Love Grass) Production requirements



(prepared for Thaba Nchu Beef Producers)

A tufted perennial with culms varying in height from 0.5m – 1.5 m, normally grows in area of low moderate rainfall, 500-1000 mm. It is very drought tolerant. The horizontal roots can spread to at least 1 metre, filling the surface soil between plants, making it very effective in using light rain and in preventing other plants from establishing. *It grows in well-drained soils.*

Temperature requirements

Optimum temperature for growth is between 17 °C and 32 °C and at a range in average annual temperature from 14 °C to about 23°C. Frost tolerance varies widely, and remain green and potentially active through the first frosts, but with little active growth. Winter survival (winter-hardiness) in severely frosted areas varies among genotypes. Weeping Love grass has persisted in areas with mean minimum winter temperatures down to -5°C. Minimum temperature for reliable stand survival of the most winter-hardy cultivars is between -15 and -20°C.

Reproductive development

Flowering patterns vary with type. *Weeping Love grass,* flower in late spring and to a lesser extent, late summer, but rarely in midsummer. It commences flowering in spring, and continues to produce large numbers of inflorescences throughout the summer, with a much higher percentage of fertile tillers.

Establishment and Fertilizer

A clean fine seedbed is essential for successful establishment. Seed can be broadcast or drilled, and covered to less than 1 cm. Rates of 1-5 kg/ha seed give good stands with broadcast sowings, although this can be reduced to as low as 0.25 kg/ha for row planting. An inter-row cultivation of row-planted *weeping love grass* during the first year helps it compete with weeds, although this is not necessary in subsequent years. Row spacing can be from 0.6-1.2 m. Good seedling vigour and rapid early growth contributes to ease of establishment. Survives on poor soils, but needs extra nitrogen for high production. Fertilizer should be added prior to planting, with recommended rates of P and K. Nitrogen may be applied at this time at rate of 10-20 kg/ha, with additional nitrogen applied as top-dressing once seedlings are well established. It spreads readily into disturbed areas such as earthworks, roadside slashing.

Growing in infertile soils under low rainfall , dry matter yields are low at 3-10 t/ha/year. In favourable environments and with adequate nitrogen and irrigation, yields of 20-30 t/ha dry matter are achievable. Yields can be doubled by increasing cutting frequency from 4-8 weeks, and more than doubled through applications of 100-200 kg/ha N. *E. curvula* has been very productive for animal production (van Oudtshoorn, 1992).

APPENDIX 1.13 Decision tree used for the development of alternative interventions for south-western Free State

The decision tree analysis was used together with the farmers to explore farm management strategic most suitable under given weather forecasts and climate predictions.

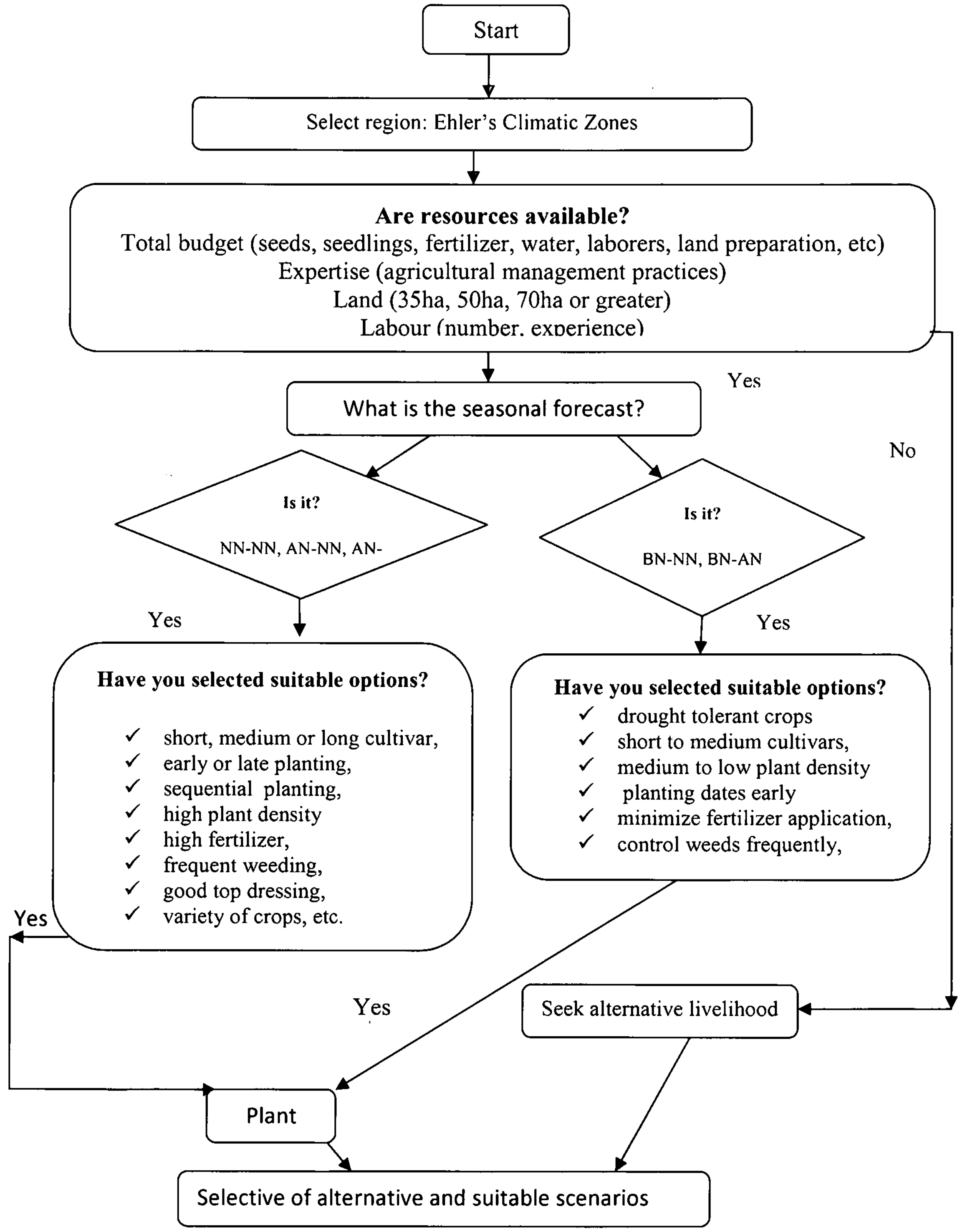


Fig. 2 Input variables used for the development of alternative decisions under different circumstances for south-western Free State farmers for decisions to plant or not, based on the seasonal forecast.

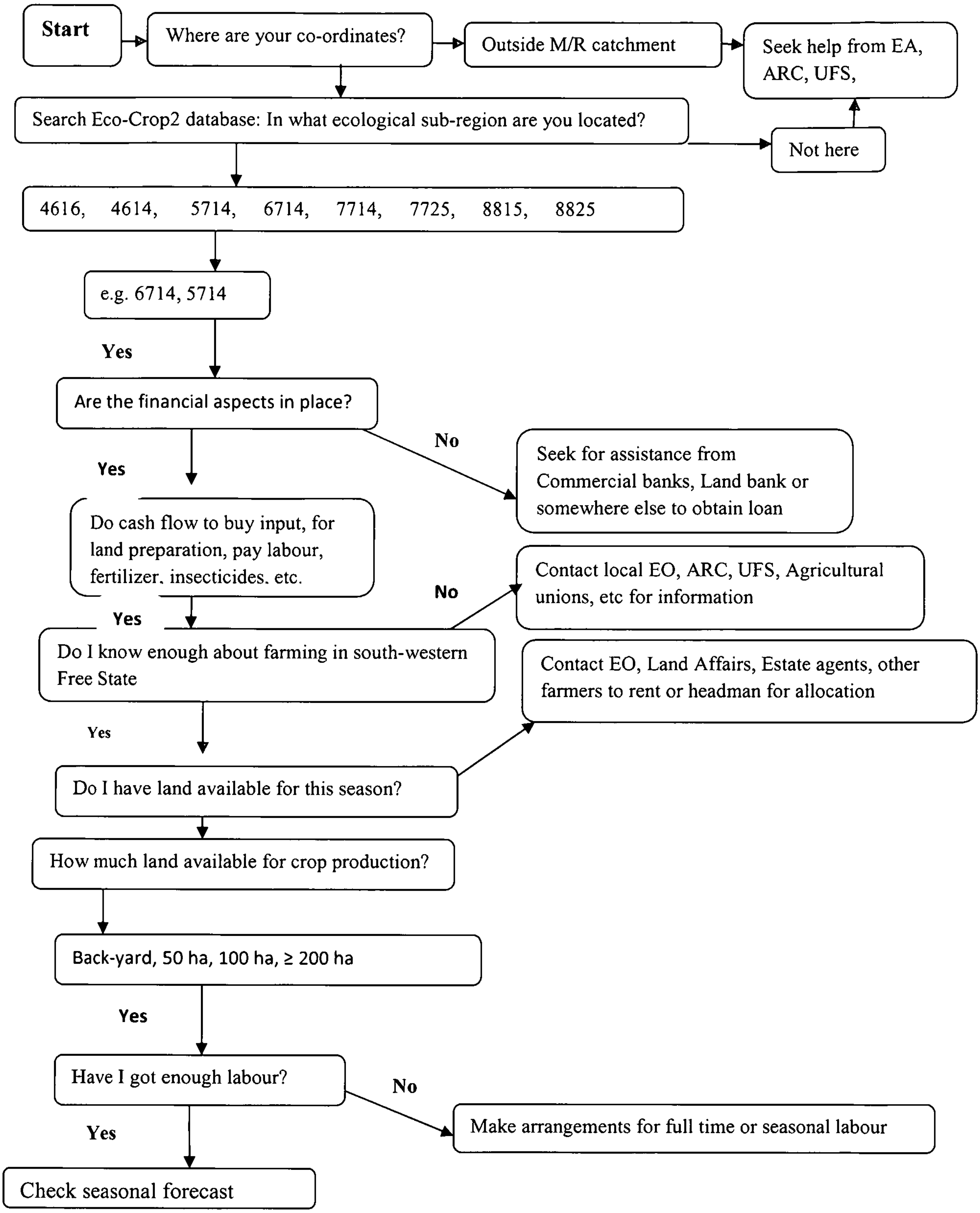


Fig. 3 Decision tree to ascertain if general conditions are in place prior engaging to field activities in Modder/Riet catchment.

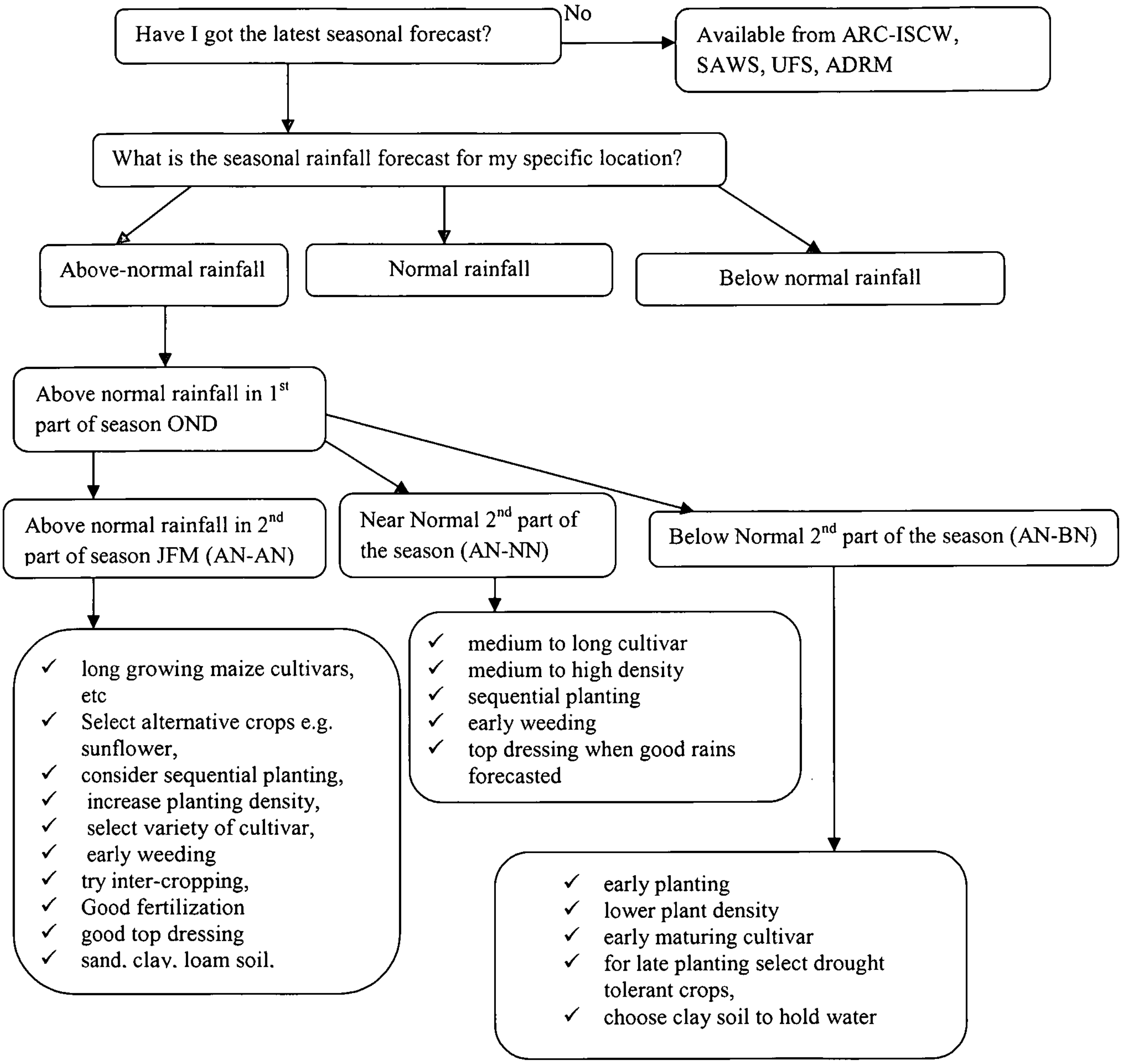


Fig. 4 Decision tree for general options for maize production under rainfed conditions in the south-western Free State when a normal to above-normal rainfall seasonal forecast is issued.

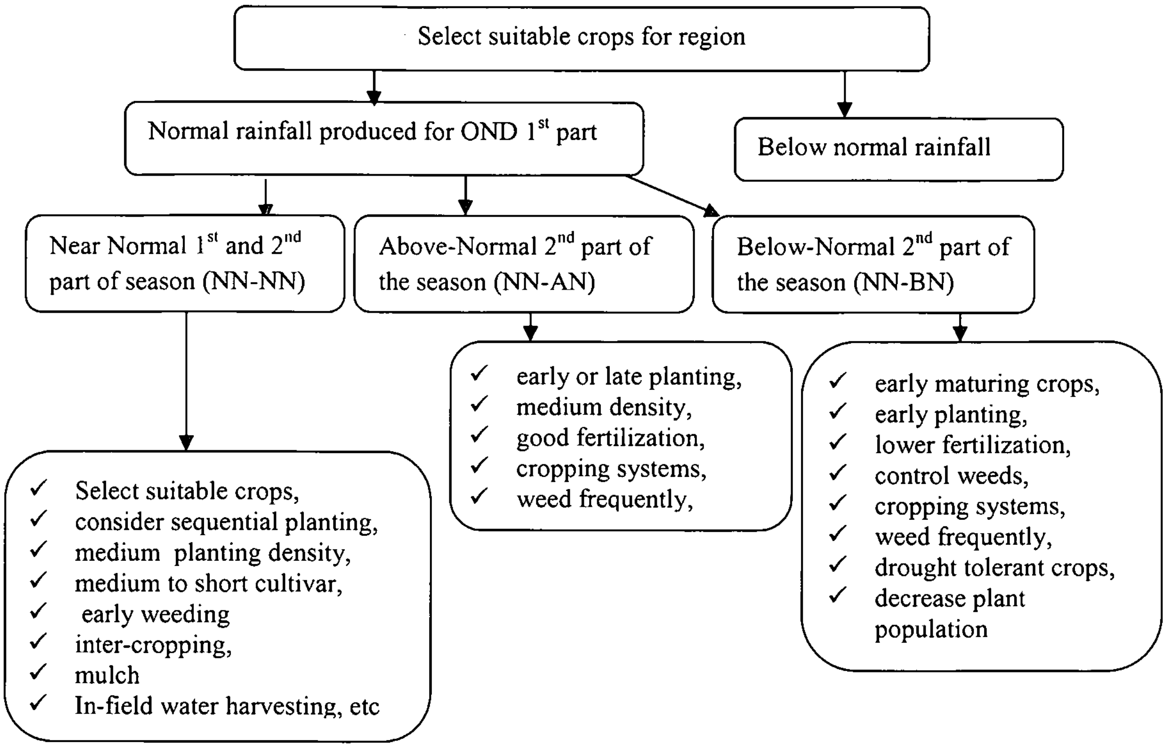


Fig. 5 Decision tree for general options for near-normal rainfall conditions.

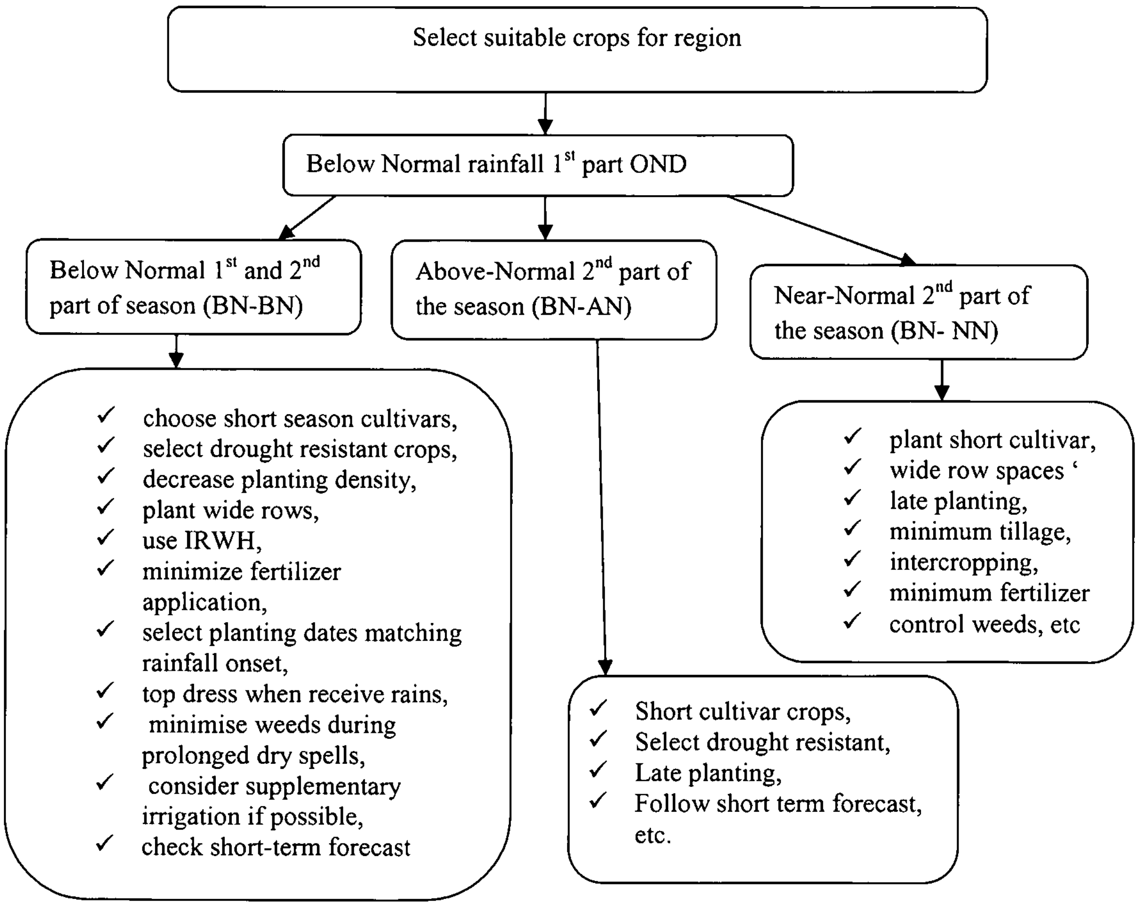


Fig. 6 Decision tree for general options for maize production under rainfed conditions in south-western Free State when a below-normal rainfall seasonal forecast is issued.

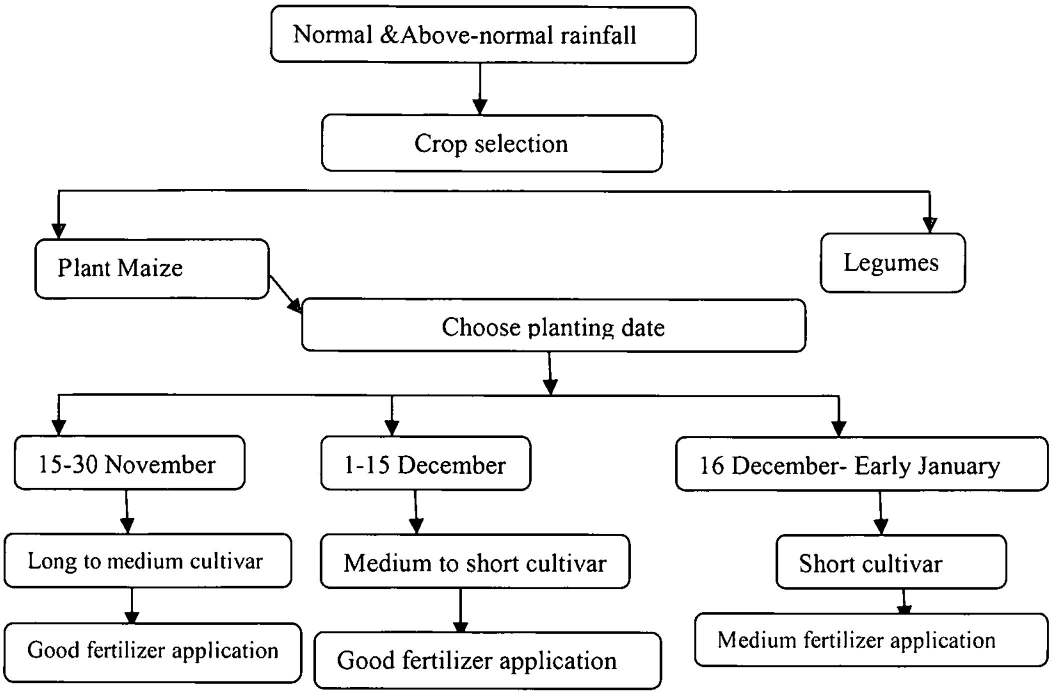


Fig. 6 Scenarios for decision-making under normal to above-normal seasonal forecast for maize production, to make planting dates with cultivar choice.

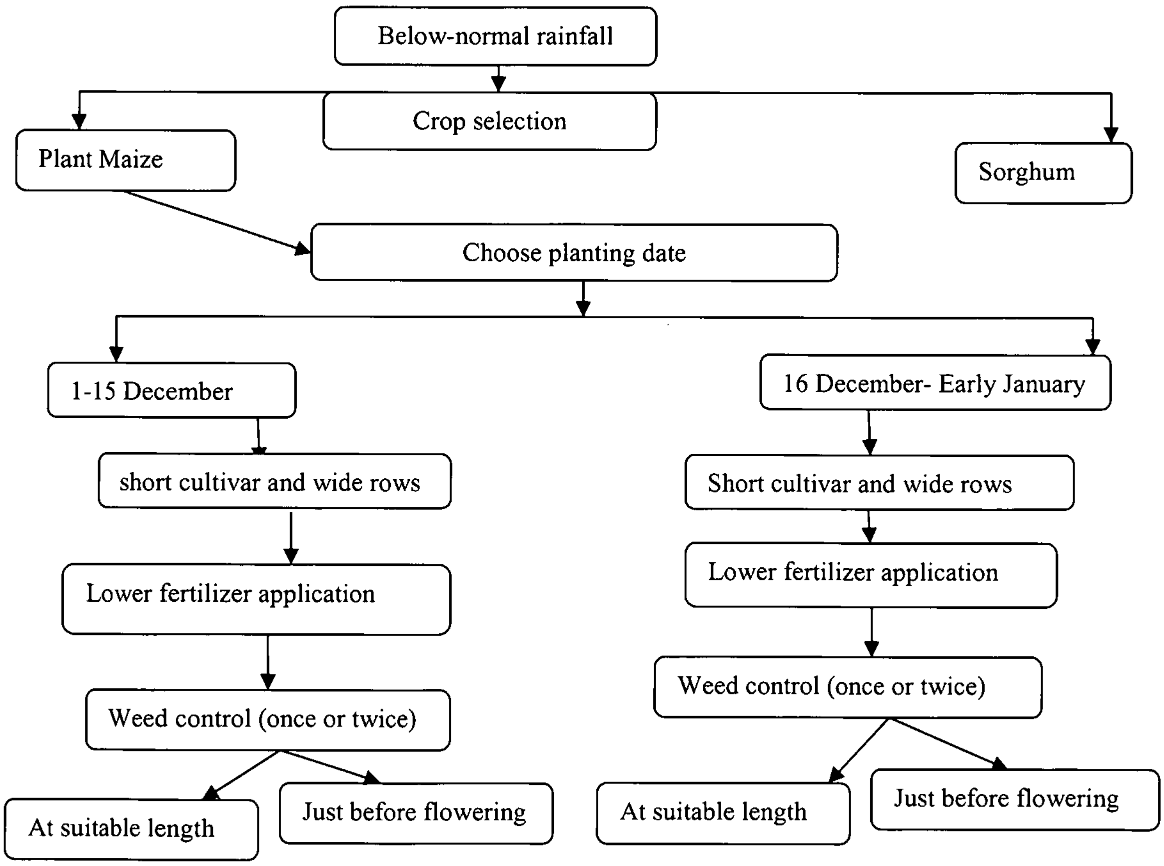


Fig. 8 Scenarios for decision-making for maize production in the south-western Free State when a below-normal seasonal forecast is issued with two planting dates and short season cultivar.

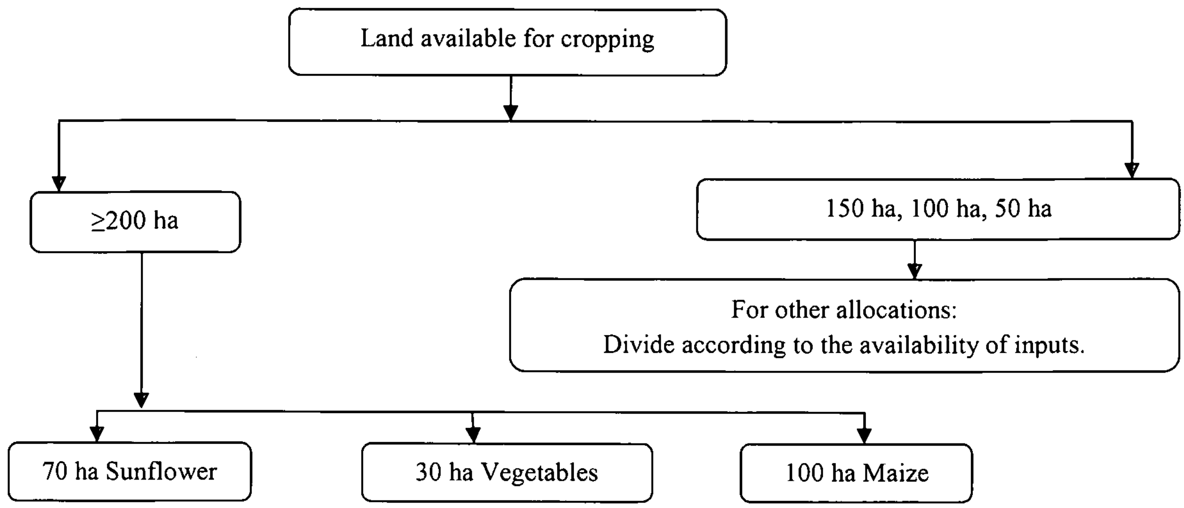


Fig. 9 An example of a decision tree on land distribution for crop production.

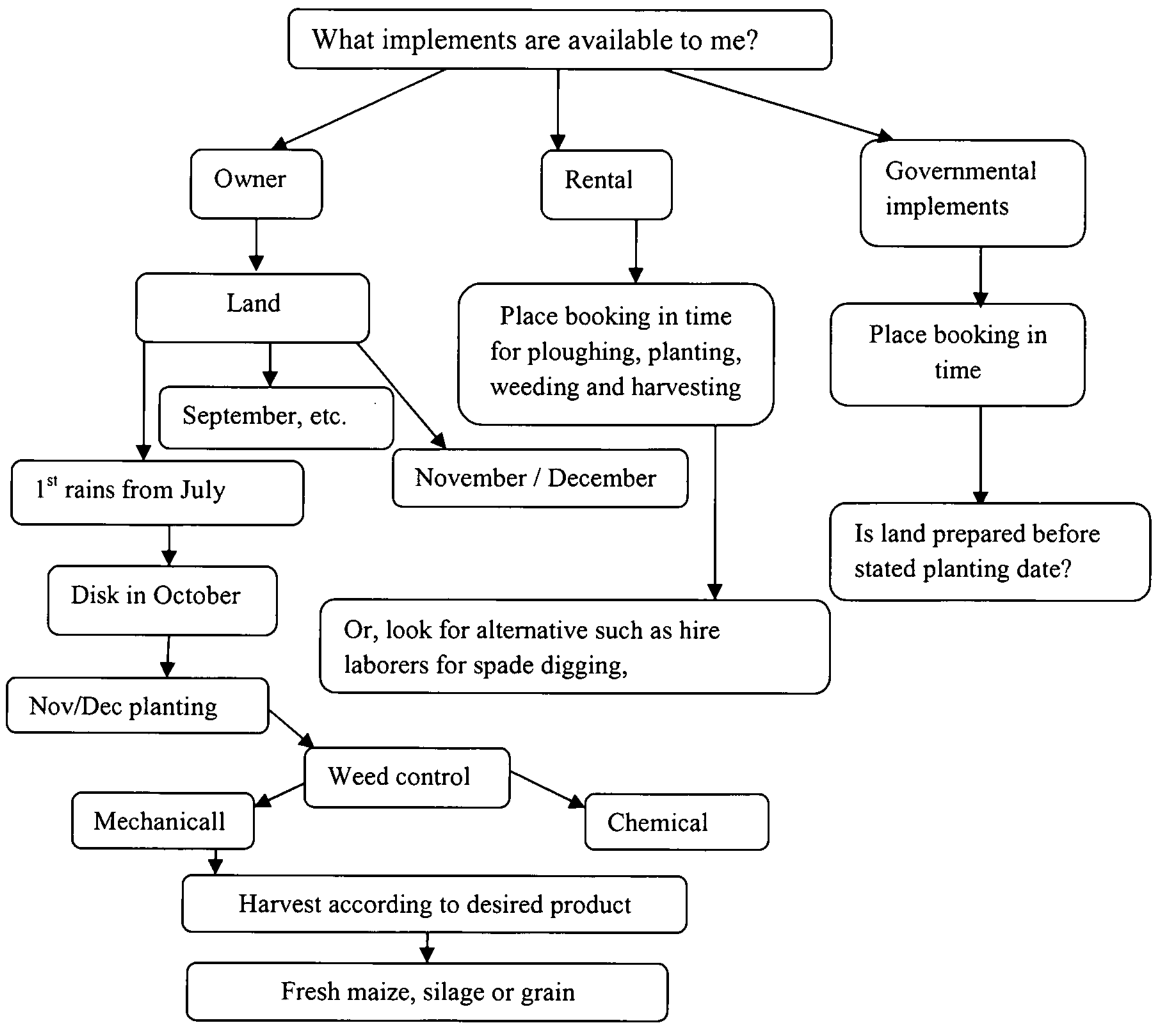


Fig. 10 Decision tree for implements request for rental and field preparation.

APPENDIX 1.14 An example of a tailor-made advisory for Rustfontein farm

Rustfontein farm is located at longitude -29°15"16', latitude 26°56"36' in the south-western Free State. The Scotts group runs a variety of agricultural enterprises in crop production and animal husbandry.

- ✓ About six rain gauges were installed on this farm to record rainfall.
- ✓ A historical daily rainfall data collection is available for analysis starting from 1954 to date.
- ✓ Rainfall records are taken on daily basis
- ✓ Maize, lucerne, wheat and vegetables are produced
- ✓ Small stock (sheep, goats, pigs and poultry) and
- ✓ large stock (Brahman, Hereford and Nguni cattle).

The long-term mean annual rainfall for Rustfontein farm is 566mm (Fig. 11). The driest years were observed in 1963/64 and 1979/80with rainfall below 350mm. The wettest years being 1955/56, 1975/76, 1980/81, 1986/87, 1995/96 and 2001/02 received above 750mm of rainfall

The seasonal rainfall forecast can guide in selecting planting dates, suitable crop types, and cultivars carefully. The lowest annual rainfall received over 50 years with the amount of 327mm in 1979/80 and the highest was in 1975/76 with rainfall amount of 848mm of rainfall.

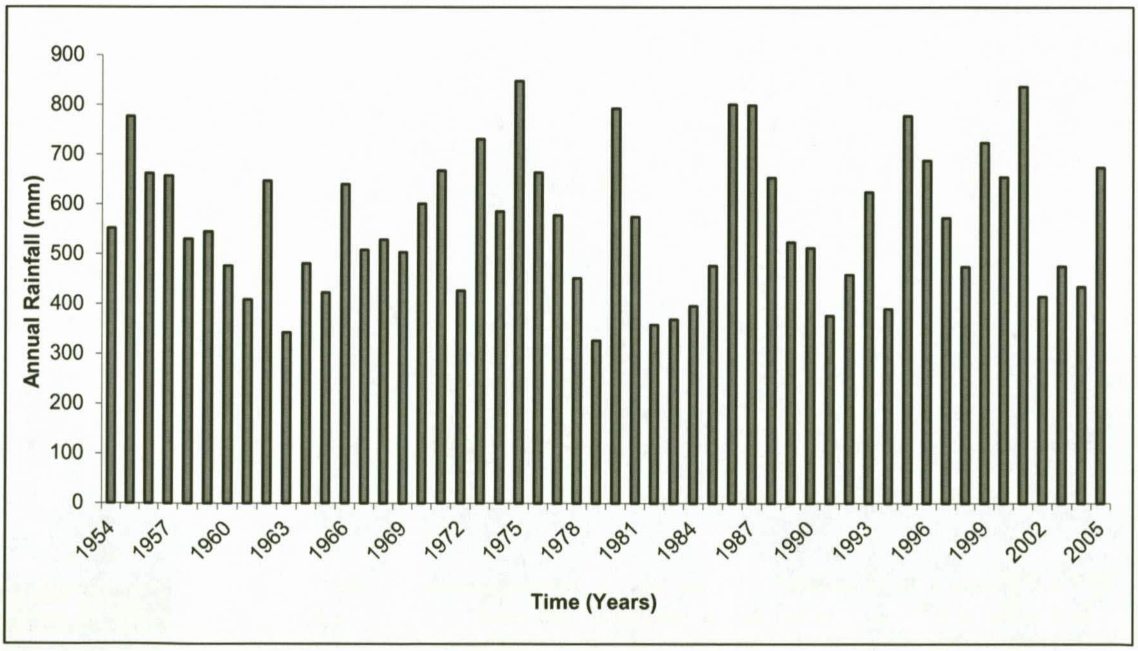


Fig. 11. Long-term annual rainfall (July to June) for Rustfontein farm used to demarcate seasonal boundaries.

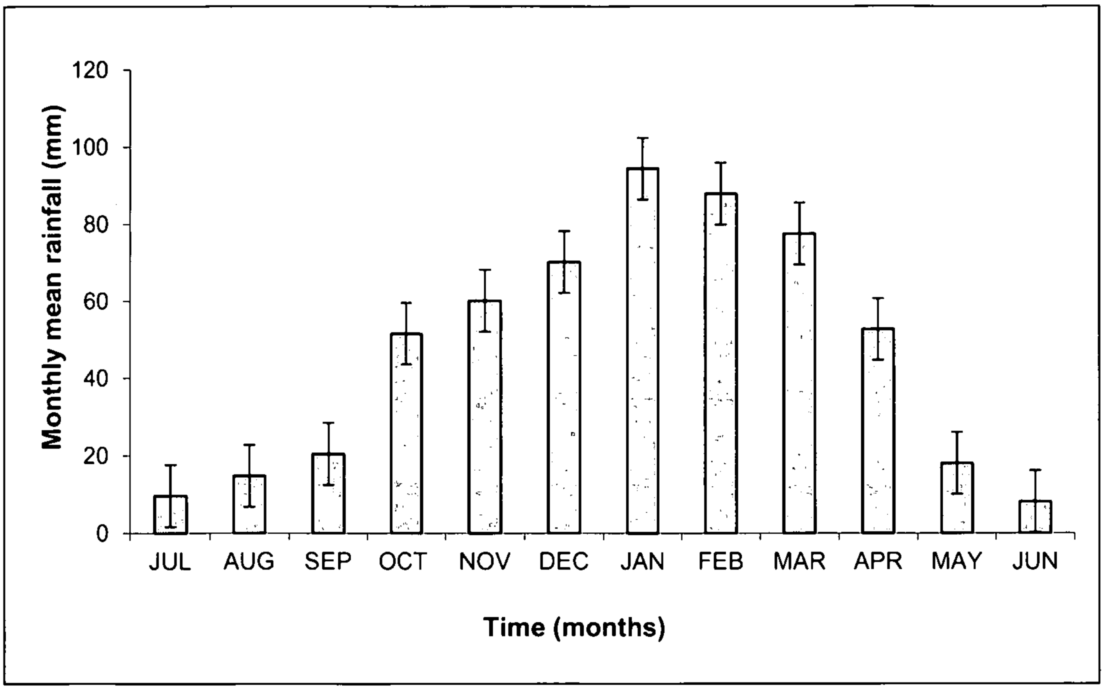


Fig 12 Mean monthly rainfall and standard deviation for Rustfontein farm

For example on maize production:

- ✓ the Scotts group for above-normal rainfall conditions was advised to increase the maize plant population from 15000 to 30000 plants/ha,
- ✓ choose short cultivars and plant late in December for 2009/2010
- ✓ plant and add few more ha for lucerne and increase the plant population
- ✓ 14-day forecast was continually checked to select rain free days for the cutting of lucerne
- ✓ Lucerne can be cut when at least 10 rain free days, as it has to be cut and dry at the field for 7 days before making bales for livestock feed during winter.
- ✓ To minimize the risk of damaging the hay and destroying lucerne. If lucerne is cut, it must be allowed adequate dry out period before baling.
- ✓ Implement firebreak in winter to avoid maize residues being destroyed,
- ✓ Avoid vegetables sensitive to frost since the farm is located in between the mountains
- ✓ Get vaccination programme from veterinary services during above-normal rainfall prediction to avoid possible outbreak of diseases amongst animals

The monthly mean rainfall and standard deviation were calculated (Fig. 12). The suitable planting season starts in October as the mean monthly rainfall greater than 40mm is received from October. Planting and land cultivation is advisable during the time when the top soil moisture is adequate. October month receive mean rainfall which is above 50 mm and so one needs to look at probabilities and chance of planting when rains of 25mm in 5 days has been received. The peak mean rainfall is reach in January which is mid-summer season. As the season mature to March the mean rainfall declines to 78 mm. In April only 53 mm mean rainfall is received. May is out of the rainy season as less than 20 mm was received on average rainfall. Lucerne can be planted from mid-September to early October as it is harvested January – February and is stored as bales for livestock feed through the winter months.

With the provision of supplementary irrigation maize can be planted as early as 1 November. Maize which is produced for silage to feed small and large livestock. Serial planting can be planned in advance, to ensure that maize is produced to make enough silage to sustain the livestock through the winter season. Fresh and dry grain maize is produced for consumption and for milling to feed small livestock.

Another example, cutting of fresh stalk maize should be done on dry days and when cut it is compacted to remove the air and covered with plastic sail to prevent air exchange or water entering, milling of grain should be done on dry days to prevent exposure to water as the maize meal might spoil should it absorb water particles.