Extension Agrometeorology a Pillar to Food Security and Sustainable Agriculture: A Case Study Mangaung Metro Municipality

Abstract

Herein faced a well-recognized scientific knowledge transfer challenge. Agricultural producers and practitioners require a widespread understanding of science, its interpretation, and its applications. Multidisciplinary agricultural scientific knowledge integration into operational and tactical decision-making serves a key function inimproved agricultural productivity and food security. The agricultural sector is challenged by a plethora of societal challenges, such as climate variability and change, extreme weather events, disease and pest outbreaks, and many other disasters. Disaster occurrences in communities across South Africa have intensified rapidly, are increasingly complex, and require multidisciplinary approaches and collaboration to address these challenges. Thus, extension agrometeorology attends to the challenges brought about by weather and climate and persistent ways for adaptation and mitigation by understanding farm microclimate and localized agricultural practices. The establishment of agrometeorological services required engaging with the farmers at the farm level. This involves educational commitments such as farm community study groups, advisory forums, Climate Field Learning, Climate-Smart Agriculture, and Agrometeorological Extension Training. The institutionalization of platforms comprising scientists, intermediaries, and farmers forms part of the extension of agrometeorology to enhance agricultural sustainability and food security.Agrometeorological information and knowledge, advisories, and services remain one of the major hindrances toward productive agriculture. Well-researched and scientifically proven knowledge is inaccessible to most potential farmers whether commercial, resource-poor, or subsistence. A noticeable gap exists between knowledge developers or suppliers and end-users such as farmers. This paper is aimed at discussing the existing gaps and practical solutions for the enhancement of proper knowledge dissemination. In this study, we discovered that most extension advisories and intermediaries indicated that 13% had a good background in the application of agrometeorological information and knowledge and 87% had no skill. About 80% followed the daily weather forecast. However, 86% of the participants could not differentiate between short-termforecasts, seasonal predictions, and long-term predictions. The need for intensive training of intermediaries on agrometeorological knowledge was emphasized since such knowledge is an integral part of agricultural decision-making toward sustainable agricultural productivity and food security.

***Keywords**: Extension, Agro-advisory, Agrometeorology, south-western Free State*

1. INTRODUCTION

Climate change occurrence has triggered a growing consensus that the agricultural food systems condition to be redesigned as it is having a profound effect on agro-food systems while agricultural activities contribute to a changing climate. Agro-food systems contribute to natural resource degradation as much as they are affected by it. Climate change deepened and resulted in food quality and safety risks, hazards, emerging new diseases, and pest outbreaks. Hazard occurrence requires a thorough transformation in food systems to attain Sustainable Development Goals, most especially to end hunger and malnutrition (HLPE, 2020). Agrifood systems face not only environmental-related challenges but also conflicts, population change, and inequalities in food access and availability and agricultural resources. The sustainability of agrifood systems delivers food security and nutrition to strengthen economic, social, and environmental conditions (FAO, 2018; Gadu, et al., 2023). Agricultural production includes a variety of systems including ecosystems, economic systems, human systems, energy systems, and health systems which offer critical contributions to the food systems (Fanzo, et al., 2020).

Climate change is one of the pressing issues for agricultural productivity, as it affects agroecosystems, agroforestry, and agroecology systems worldwide (Abegunde et al., 2019). The impacts of disasters exacerbated the changing climate affects already compromised agricultural communities with limited resources and a lack of scientific knowledge to support decisions. Subsequently, local governments and agrarian departments are not well-equipped to deal with multifaceted climate change challengesin agroecological zones (Sokona et al., 2021; Ziervogel., 2014).

The agricultural fraternity involves multidiscipline expertise, and each discipline is crucial for fundamental decision-making. Agrarian production further requires critical multistakeholder collaborations to roll out sustainable agricultural production practices towards food security and farmer development (Lockeretz, 2012). These role players necessitate critical roles in the development of farmers and for localizedclimate change adaptation strategies adoption. Integrating multidisciplinary approaches from agricultural research, policy development, advisory services, and training is integral to strengthening agri-food systems and eliminating hunger (HLPE, 2020); Sivakumar, et al., 2000). The South African region's agricultural sector is the land of contrast and dual economics, comprised of well-established commercial farmers and poor resource farmers. Therefore, the critical principles for ensuring food security are dependent on indorsing agrometeorological advisory services, intensifying training of agricultural advisors, farmers training, and knowledge transfer.

Food security and nutrition interconnect several proportions inclusive of human beings, the environment, institutions, inputs, and the overall agricultural value chain while improving socioeconomic and agricultural outputs (HLPE, 2020; Berry et al., 2015). The intergovernmental outlays the importance of food security dimensions to preserve and promote one health concept for sustainable agricultural produce and nutrition. These dimensions require processes that foster and put emphasis on the conservation of natural resources, biodiversity, and agroecosystems (Clapp, et al., 2022). Thus, to achieve the Agenda 2030, provinces adopt policies on radical transformation of food systems to eradicate hunger and malnutrition by understanding ecological context-specific diverse solutions (HLPE, 2021). The sustainablefood system that supports the interconnected food security dimensions revolves around, availability, access, utilization, stability, agency, and sustainability toward fulfilling Sustainable Development Goal 2 (SDG 2) which is zero hunger. This paper contributes to the agency dimension of food security by the application of agrometeorological knowledge to farmers across the Mangaung Metro Municipality. The agency seeks to address the uneven access to information, knowledge, and technology by farmers (Clap, et al., 2022, HLPE, 2020; HLPE, 2021,). The disparities in wealth, income, and level of education have a major impact on knowledge inaccessibility affecting choices. Agrometeorological knowledge is the key to making informed decisions on soil-plant-animal-atmospheric relations, this kind of knowledge guidesinselectionof suitable agricultural enterprises and practices that bring about driven solutions.

The initiatives undertaken by the researchers and agricultural advisors in the Mangaung Metro Municipality in the Free State Province of South Africa seek to redress the existing disparities relatively. Predominantly, these initiatives are about equipping farmers with science-based knowledge and strengthening the facilitation of resource accessibility, utilization, and improving decision-making and adaptation strategies on farms (Mutimba, 2014; Van Niekerk, Stroebel, van Rooyen, Whifield, & Swanepoel, 2009). The study area is located in the southwestern Free State and is comprised of well-established commercial farmers, up-coming commercial farmers, poor resource farmers, and subsistence farmers.

The agricultural sector is vulnerable to many challenges triggered by climate irregularities that impact the environment, soil fertility status, crop types, livestock adaptability, and overall agricultural productivity. Thus, the packaging of agro-advisories had to have a combination of knowledge including, soil types, crop suitability, livestock adaptability, tailored technologies, weather forecasting, seasonal prediction, planting practices, and pasture management. The selected extension approach requires elements that address the needs of the farmers, as it has to deliver the local-specific challenges and be context-specific. The knowledge transfer gap between generators, supply, and end-users is a big challenge for the agricultural fraternity. Therefore, the authors of this paper suggest that a peculiar extension approach to disseminating agrometeorological information has to be tailor-made and user-friendly. Thus, simplicity, comprehensibility, applicability, use of local languages, and avoidance of scientific terminology are essential. Feasible establishment of structured agrometeorological advisory channels, participatory action techniques, tailored and point-specific knowledge to minimize the effects of climate irregularities (Bush et al., 2017, Vaughn, et al., 2020). The development of the extension agrometeorology through operational study groups is fundamental for establishing communities that are well-equipped to make sound operational and tactical decisions toward sustainable agriculture. This shall equip farmers to adopt and include weather forecasts and climate predictions andimprove agricultural sustainability and agroecosystems for food security assurance, sustainable produce supply, and income generation. Plant growth, livestock farming, and agroforestry undergo a variety of phases during their life cycle, which is affected by weather conditions and subjected to biotic and abiotic stressors (Davitt, et al., 2011; Seleiman et al., 2021; Wahl, et al., 2011). The most troublesome abiotic stressors occurring in the study area that are climate-related are storm winds, extreme temperatures, drought, floods, hailstorms, and wildfires, while biotic stressors include living disturbances such as detrimental insects to agricultural production (Kanninena, et al.,2013, Zuma-Netshiukhwi, 2013). The development of tailored agrometeorological advisories and services is crucial to minimize extreme weather and disaster consequences. Training provision for agricultural advisors and intermediaries remains the most crucial part of knowledge transfer and services establishment in farmers' fields (Zwane, et al., 2015; Weiss, et al., 2000; Stigter, 2010; Winarto & Stigter, 2011, Zuma-Netshiukhwi, 2013).

The application of agrometeorological knowledge in this study area stimulated different perspectives and made major changes in the availability of agrometeorological information and knowledge, advisories, services, and identified structured channels and methods of dissemination. The most effective method of information/knowledge dissemination differs from farmer to farmer and is predetermined by the farmer's capabilities; resource-poor farmers in the study area mostly utilize the study groups, WhatsApp, the internet, and short message services. Also, 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 advisories and 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 knowledge and services would ideally require interaction with agricultural advisors to obtain knowledge on weather forecasting, seasonal predictions, climate variability, crop suitability/selection, cultivar selection, livestock adaptability, climate change adaptation and mitigation and other agrometeorological related knowledge, to strengthen agrifood systems, agroforestry, and agroecology.

2. MATERIAL AND METHODS

2.1 Selection and Description of the Study Area

Mangaung Metro Municipality is located in the Free State province in the central part of South Africa, covers 9 887 km^2, and comprises three prominent towns which are Bloemfontein, Botshabelo, and Thaba Nchu (Figure 1.1). The Free State province contributes fairly to agricultural production and is number five in the agricultural households in South Africa (Cowling, 2023).

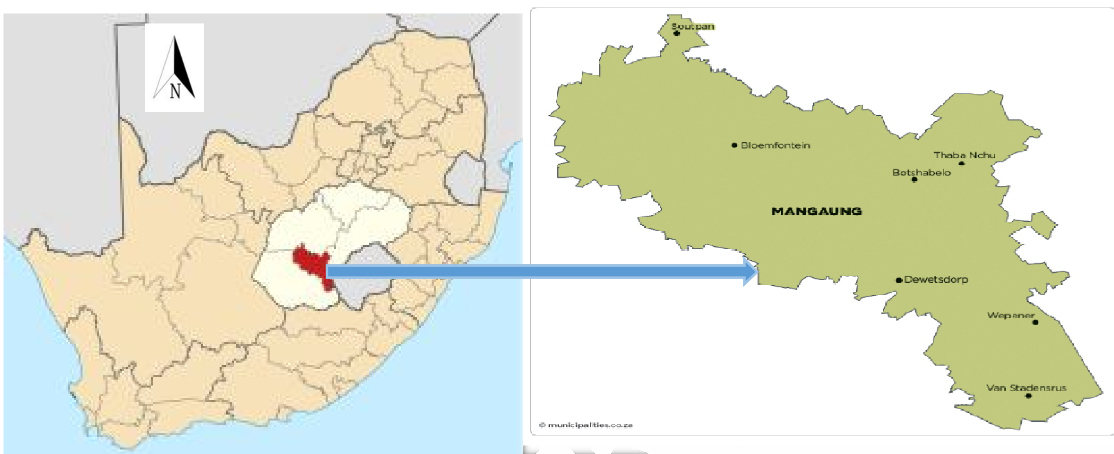

Figure 1.1 A map showing the South African districts and Mangaung Metro District in the Free State province of South Africa

A multi-stage sampling procedure was implemented for the selection of the location in which the study group has the required characteristics (Mugenda and Mugenda, 2003; Suleman and Hussain, 2018). The multi-stage procedure followed the definition and clustering of the population, randomly selection of the clusters, and random sample study groups from within the selected clusters. This sampling procedure involved the purposive selection of units of observation or study groups of areas based on their high agricultural production potential, which was Mangaung Metro Municipality at its extent.

2.2 Research Design

This investigation adopted a cross-section research design, action research, and Farmer's Systems Approach for Development, whereby qualitative data was collected from different farmers at a specified point in time to observe variables while avoiding influencing unit observations. The cross-sectional research design was sufficient to provide critical analysis of, and drawing of perception from, subjects and experiences. Cross-sectional research designs employ data from multidiscipline, and multi-stakeholders and isefficient to use

(Creswell et al., 2017; Abegunde et al., 2020). Furthermore, the design was selected due to its appropriateness for this study as it provides time and cost efficiency, and rational conclusions to ascertain challenges resulting in a lack of agrometeorological knowledge applications, poor agricultural productivity, and food insecurity. Since the study incorporated qualitative research, a cross-sectional design permits the use of a Participatory Rural Appraisal Approach. Cross-sectional research design permits the use of close-ended questionnaires,structured interviews, focus groups, and probing questions as a research tool for this manuscript.

An action learning cycle was used in the Farming Systems approach to Development,FSaD where necessary, leading to the improved dissemination and application of weather/climate information and products/advisories in agrometeorological decision-making for improved livelihoods. Action learning cycle also described as, plan-act-observe-reflect (Dick, 2002; McNiff, 2002; Tenge, 2005; Kramer 2007; Stringer, 2007; Serrat, 2008; Kelman, et al., 2009) was 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. FSaD approach is comprised of four distinctive phases as follows: (a) Diagnosis or description of farmers' needs about the agrometeorological information and advisories and services.(b) Designplanning 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. (c) Testing and implementation through farmer-managed experiments according to planned interventions and activities. (d) Dissemination and impact assessmentusing dissemination methods as preferred by the farmers. These approaches further provide empirical evidence on the underlying factors influencing agrometeorological and other science-based knowledge adoption levels for informed decision-making and to draw robust conclusions.

2.3 Description and Selection of Responds

The earmarked population for this study were the farmers at all levels and Agricultural Advisors in the Mangaung Metro Municipality. Representative sampling was conducted in study groups and farmers were selected based on potential in agrarian practices, which was according to the local Agricultural Advisors and records furnished by the Department of

Agriculture and Rural Development in the Free State. A total of 394 farmers and 30 Agricultural Advisors amounting to 424 sample size on just one municipality was used in this manuscript. The sample size was entirely determined by farmers' availability and willingness to participate in study groups.

2.4 Data Collection

A survey method was conducted for qualitative data collection through, Participatory Rural Appraisal Approach tools and techniques, through structured interviews using close-ended questionnaires,focus group discussions, key informants, and buzz questions. The use of questionnaires wasbased on eliciting detailed information for descriptive analysis to reveal empirical evidence from the study. The questionnaires were verified for relevance, competence, appropriateness, and effectiveness of the questions in capturing data desirable for the study. This study alsogained a better understanding of the typology (homogeneity or heterogeneity) of the target group and identified vital issues affecting the use of agrometeorological knowledge for decision-making in the agroecosystem.Questionnaires were conducted at the farm level, and during monthly study groups. Data were collected on the socio-economic characteristics of farmers, agrometeorological knowledge, weather forecasting and seasonal prediction, and the yield from agricultural production among others.The respondents were requested to sign informed consent forms before they took part in the research.

2.5 Data Analysis

The factors influencing the adoption and the use of weather forecasting, seasonal predictions, agrometeorological, and other science-based knowledge by the targeted participants in the study area were scrutinized descriptively. A comparative assessment through percentage quantification was examined using Microsoft Excel Statistical analysis, the use of flow charts, a list of challenges, gaps, and recommendations, evidence-based examples for farmers who adopted agrometeorological applications, and the adoption of knowledge domains.

3 RESULTS AND DISCUSSIONS

3.1 Conceptual Framework for agrometeorological applications

The main objective of agrometeorological applications is to enhance agricultural productivity, food security, agroecosystem and to improve agricultural revenue. This idea of the agrometeorological application framework integrates objectives to enhance the use of agrometeorological knowledge, agricultural productivity, agroecosystems, and food security under climate variability (Figure 1.2). Along with climate smart agricultural innovations and techniques, agricultural practices that contribute to efficient natural resource use and management. The development of the agrometeorological applications framework was shaped by the responses given by the farmers on agricultural knowledge availability, agricultural practices and agricultural production status. The adoption of the use of weather forecasting, seasonal predictions and science-based knowledge improve amongst farmers with time and when the confidence has been built and observed from other participants.

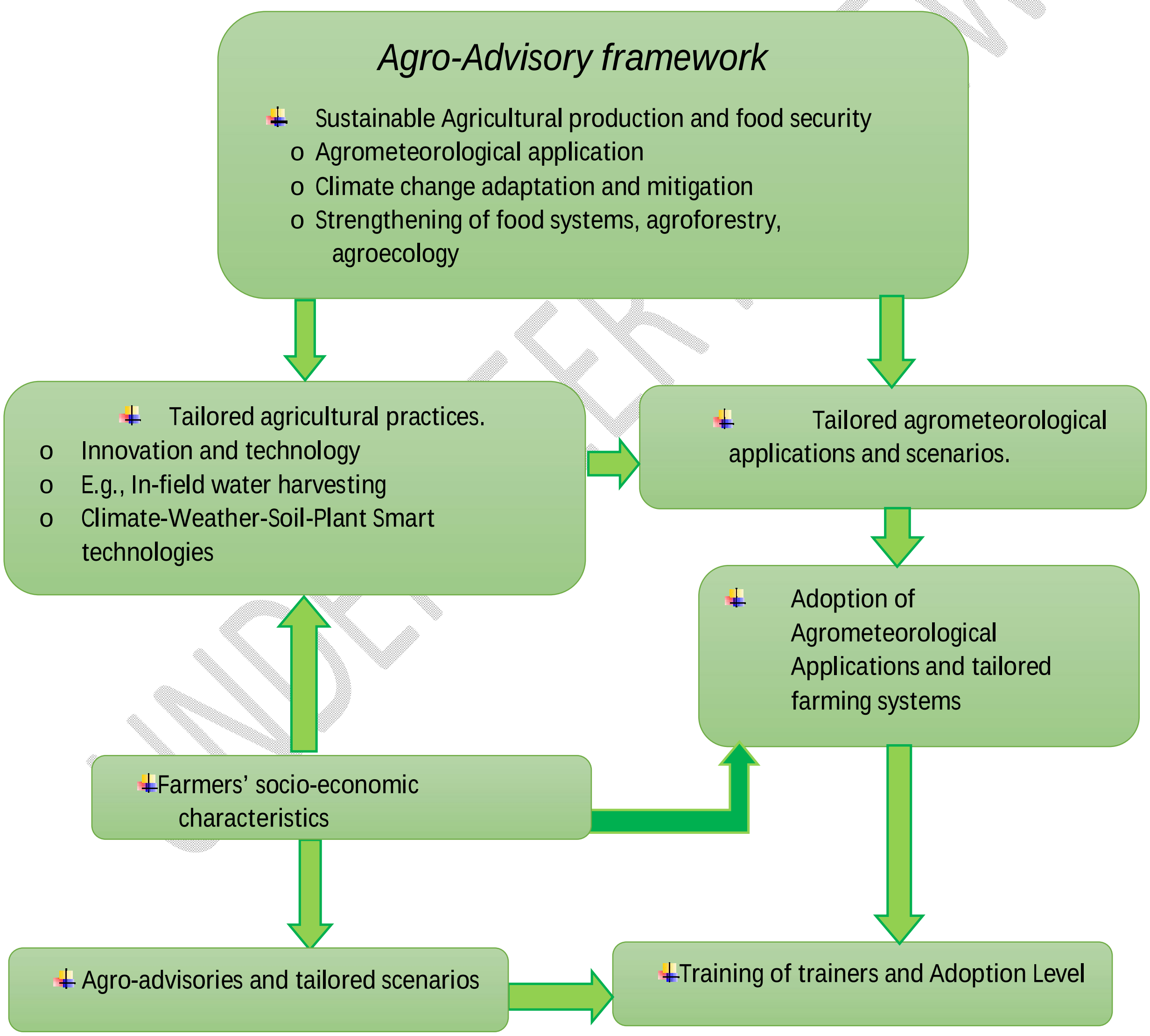

Figure 1.2. Conceptual framework for the adoption of agrometeorological knowledge among farmers

3.2 Challenges faced by the farmers.

The results show that smallholder farmers constituted of a higher proportion of a sampled farmers who had no access to weather forecasting, seasonal predictions and agrometeorological knowledge. It further indicated that commercial farmers in the study area were privileged enough to have resources and access to science-based knowledge. The results on the challenges contributing to poor agricultural conditions and productivity on Mangaung Metro Municipality was that Agricultural Advisors had no basic knowledge, understanding and training in agrometeorology and its applications to agricultural decision-making.

The farmers identified a number of challenges that were considered the major cause of hinderance to the accessibility of agrometeorological knowledge,science based knowledge, agro-advisories, services, dissemination structures and flow from suppliers to the rightful end-users.

These challenges included the following:

- ✓ Lack of basic training on weather and climate knowledge
- ✓ Lack of training and understanding on basic operational agrometeorology
- ✓ Non-existence of communication between suppliers and end-users
- ✓ Non-existence of tailored agrometeorological advisories/services available to farmers
- ✓ Lack of skills to interpret weather forecasts and climate predictions for agricultural use
- ✓ The potential suppliers of agrometeorological information or knowledge or advisories or services are not known.
- ✓ Well structure channels of information and knowledge dissemination are non-existence.
- ✓ Available agro-advisories are generalised, misunderstandable and not point specific.
- ✓ No feedback mechanism from users to suppliers of agrometeorological information/advisories for its validation

Thus, facilitation of training of Agricultural Advisors became an inevitability in the study area to since intermediaries engage closely with knowledge generators and end-users.The intermediaries have major roleto the processes on agro-advisories dissemination and ensuring the knowledge application and ensuring that farmers acquire more self-reliant and independent in their agricultural practicesand for the establishments of an extension agrometeorology (Stigter and Winarto, 2012) across the south-western Free State. The aim was to capacitate intermediaries with agrometeorological skills and expertise. The covered topics of interest were the operational agrometeorology, in relation to crop management, 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.

3.3 *Agricultural extension response to agrometeorological learning*

The results on contact with intermediaries reveal that sampled farmers had more access for advisory role. The access to intermediaries and provision of agro-advisories is crucial in the development of adoption of agrometeorological knowledge, weather-climate smart agricultural practices and tailored innovations. Contact with intermediaries statistically has a high level of confidence and positive effects on agrometeorological application and climate smart agriculture (Abegunde et al., 2020).Agricultural Advisors and other intermediaries who are well-trained in agrometeorological applications became crucial in providing informed advice for farmers to make informed decisions. During this study, it was evident that the level of Agricultural Advisor and farmer contact enabled and increases the likelihood of the adoption of scientific based knowledge relating to weather and climate toward sustainable agricultural productivity and food security. It is also evident that the higher the frequent contact with intermediaries enhances the chances of agrometeorological knowledge, agricultural practices that can be adapted to climate variability and shocks for food security.

The intermediaries were trained on climate data monitories, the applications of weather forecasting and seasonal prediction and its impact on agricultural productivity. The results on the role of operational agrometeorology indicated that it is a pillar of successful farming and strengthening of food security toward hunger eradication and for fundamental agricultural decision making. The findings indicated that about 13% intermediaries had understanding of agrometeorological applications and 87% had minimal knowledge. Only about 20% had no means to follow daily weather forecasts and climate predictions, while 80% had access to a variety of media platforms. Results on rainfall forecasts indicated that 56% of agricultural advisors had no direct access, 36% had direct access from the different weather service suppliers and 6% had access. The findings on the level of understanding and interpretation has shown that 86% had no experience, and 14% was knowledgeable. Intermediaries indicated that 80% farmers had no access but 16% had access. Result on agrometeorological knowledge show that 97% required to receive it, but 70% doubted the reliability of the weather forecast and seasonal predictions. The findings on the understanding of agrometeorological terminology show that 90% of all respondents had better understanding, but 10% had no knowledge. The understanding of probability was familiar of 79% of respondents.

The intermediaries and farmers who invested and committed their time to learn from the study groups improved on agrometeorological applications, production and profits.The multistakeholder engagement resulted to the development of localised early warning systems and monthly study groups for the dissemination of knowledge and facilitation of learning and knowledge transfer environment. Structured channels on knowledge transfer are crucial to qualify involved partners and the type of knowledge generated. The flow of knowledge transfer in the south-western Free State for agrometeorological advisories in illustrated in Figure 1.3. The agrometeorological advisories are developed at national level and disseminated to provincial with an intention to be distributed further to the local level. However, most end-user has reported to have no access to agro-advisories. There is non-existent of feedback mechanism nor initiatives mentioned by farmers to have access to localised agro-advisories.

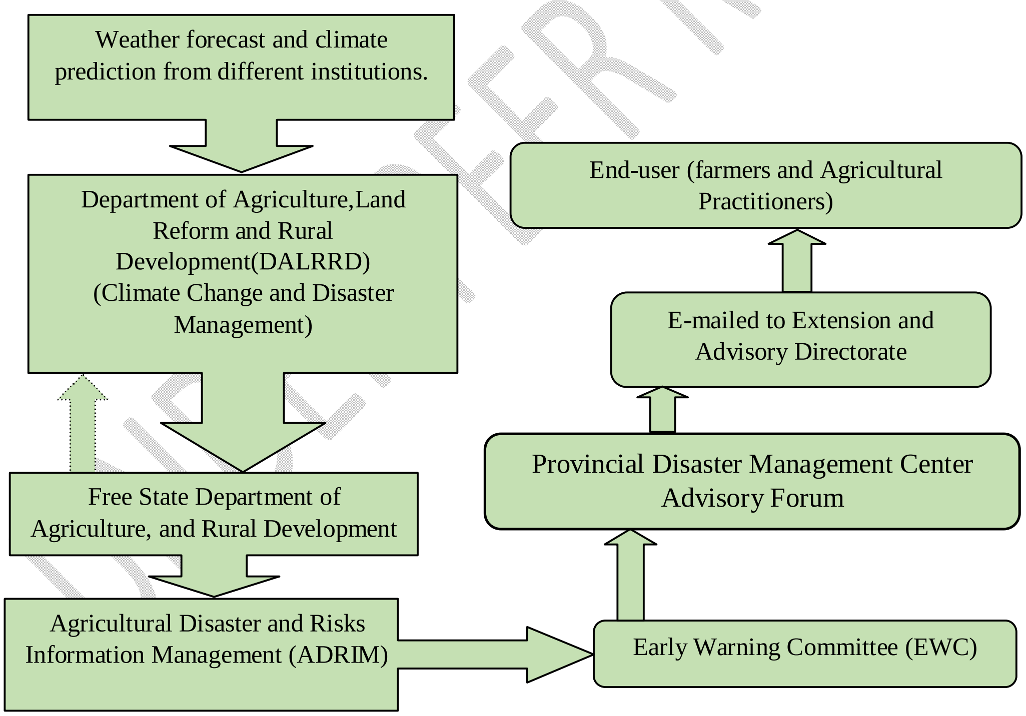

Figure 1.3: Current flow ofdissemination of agrometeorological advisories in the south-western Free State.

The following recommendation were proposed that the Department of Agriculture and Rural Development and its entities should consider implementing the following thoughts:

i. to engage with a group of weather forecasters using different Global Circulation Modelsto request, downscaled climatic conditions per region at a high resolution,
ii. to employ a qualified team of agrometeorologists to develop tailor-made advisories per region and where possible per farm (Gommes et al., 2010), for the development and facilitation of agrometeorological knowledge and advisories.
iii. to encourage the development of tailor-made advisories which strengthen diverse farming methods and sustainable agricultural development,
iv. to implement conducive strategies of information dissemination as preferred and suitable for different farmers
v. delegation of weather forecasters/climate predictors and agrometeorologists to train extension agents during their monthly regional Advisory Forums
vi. ensure dissemination of client friendly agrometeorological information/advisories/ services from intermediaries to farmers
vii. strategize and develop a two-way communication from farmers to intermediaries so that farmers' concerns can be sent back to advisories/services developers (Figure 1.5)
viii. a two-way communication to give extension/feedback from farmer to farmer may positively influence the degree of application of agrometeorological information/advisories/services (Figure 1.4).

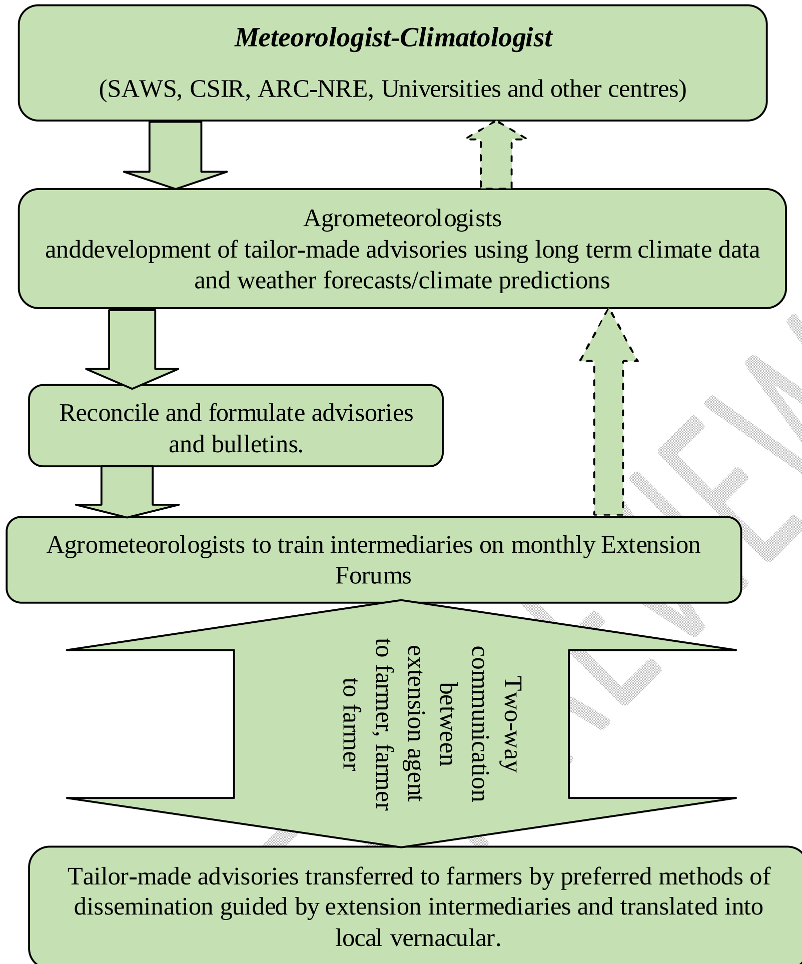

Figure 1.5: Recommendedstrategies for agrometeorological development and dissemination.

The organized monthly study groups in the south-western Free State was ranked the most suitable manner of knowledge dissemination of agro-advisories through intermediaries. Study groups allows farmers to farmer, advisor to famer and researcher to advisor knowledge exchange for sustainable farming. The agrometeorological knowledge is truly relevant to the changing climatic conditions to minimize the impact of severe extreme meteorological and climatic events. Intensification of Agrometeorological Information days could benefit intermediaries and the end-users to develop and make informed decision toward improved agricultural sustainability and productivity. The proposed two-way path for knowledge dissemination is illustrated in Figure 1.5, with emphasize to the implementation of feedback mechanism to enhance the development of tailored agro-advisories.

3.4*Evidence-based agrometeorological applications*

During the engagement with the farmers, assessment and evaluation of the availability and the application of agrometeorological information, knowledge, advisories and services in the study area.The participating farmers were monitored from inception to project completion to determine the performance, quality of production and yieldsthe indicator.The participating farmers were furnished with agrometeorological knowledge. Exposure to such type of information was gradually adopted by the farmers and the extension agents. Participatory approach contributed to building agreement and collective learning during farmer discussions. farmers increased self-confidence in application of agrometeorological information, advisories and services and lead to substantial change. The study groups presented a very diverse situation in terms of experiences, challenges and needs that are related to their farming. A successful farmer should understand the local trends in climate change and how agricultural outcomes are influenced. For example, the concept of response farming (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. Record keeping played another new role for farmers to record all activities implemented on-farm against time (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 farmingand prompted timely provision of weather forecasts, seasonal predictions and other science-based information. For example:

- ✓ Swiss chard producers, 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 and to practise conservation agriculture as improved preparedness to allow continual and frequent market supply for winter and summer season.
- ✓ Farmers with access to water were encourages to give provision for supplementary irrigation and sequential planting was adopted. For example, in one farm: the 1^{st} transplanting was conducted in the 2^{nd} week of July when15000 plants/0.5ha of Swiss chard was transplanted. The 2^{nd} transplanting took place in the 2^{nd} week of September with again 15000 plants/0.5ha and the 3^{rd} 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. 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.

- ✓ Most farmers, who only chose to supply cabbage, were able to make adjustments and introduce different cabbage cultivars for winter and summer season (Table 1). Sequential cropping was also adapted by famers for continual supply to the market.

Table 1 An example of sequential cabbage planting adopted by farmers in the study area

Planting date	Cultivar	Number of hectares	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

3.5 *Farmers response to agrometeorological learning*

The concept of an extension agrometeorology approach (Stevens, et al., 2006; Stigter and Winarto, 2012) holds great possibilities to train intermediaries and farmers on the application of science-based information. 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 was emphasized for improved production.

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 and services generation/development by intermediaries for farmers as end-users, Stigter's conceptual and diagnostic framework applies (Stigter, 2006) (Figure 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).

This end-to-end model was indirectly witnessed for the duration of this study to be an appropriate model to close the existing gap between extension agents and farmers for improved livelihood. In the C-domain, different types of basic and derived knowledge such as long-term climatic data, soil characteristics, frost probabilities, climate bulletins, crop types and cultivars, crop suitability were used to run models and generate another 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.

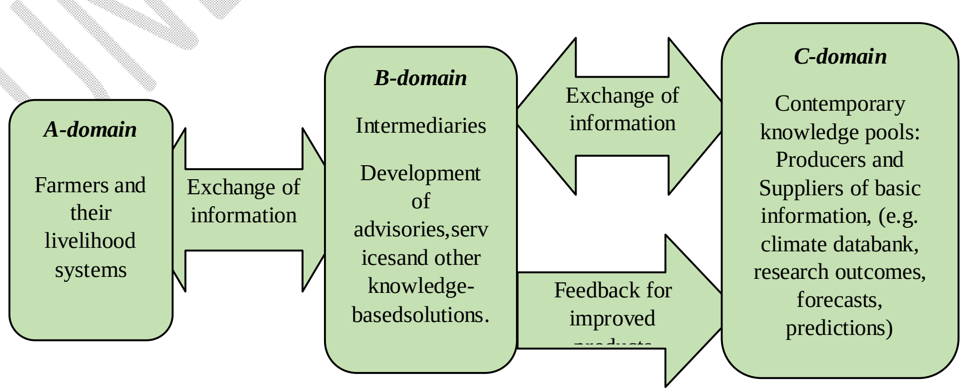

Figure 3. End to end information flow for farmerlivelihood problem solving with B-domain showing intermediaries involvement producing applicable solutions to be used in farmer livelihood(Stigter, 2006; 2010).

The B-domain put emphasis on the training of the trainers which are the intermediaries. 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 research diary whereby 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 had a negative impact for the farmers of their concern. Good decision making supported by the application of agrometeorology awards farmers with better yields.Advisories entailed recommendations on crop type selection, cultivar selection, planting date selection and basic management strategies.

Therefore, 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 and Rural Development can be effective by training advisors and extension agents to be well-equipped to train the farmers. Intermediaries, should focus on taking part in this new extension agrometeorology approach, and 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); and
- ✓ Giving feedback to the information producers for further improvements according to the needs of the farmers.

The above approach can be adopted on 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 and strength the relationship amongst information producers, local extension agents and users.

4 CONCLUSION

A number of studies worldwide have been conducted to understand the factors and impact of adopting agrometeorological knowledge, weather forecasting, seasonal predictions, agro-advisories and services by farmers at its all level of operation. The study identifies and fills the gap by addressing factors leading to poor agricultural production in areas with high soil potential for agricultural use. The adoption of agrometeorological knowledge and other science-based knowledge have a crucial role in shaping how things are done toward the betterment of on-farm decision making.

This study found a plethora of factors such as level of education, natural resources, access to agricultural advisors, exposure to media, production activity, access to agro-advisories and perception of climate variability and change are significant determinants of agrometeorological knowledge adoption level among farmers in the south-werst Free State. The results of this study are of critical significance to the provincial government, provincial Department of Agriculture and Rural Development, Agricultural Research Council, Universities, policy makers,other organizations and stakeholders with interest in the agricultural sector within South Africa.

The study examined an approach that is suitable for the delivery of agrometeorological information, advisories and services with south-western Free State. The study has highlighted the challenges faced by the farmers, by extension agents and agrometeorological information producers and suppliers. The main challenge encountered was the existing gap between the information suppliers and users. Therefore, end-to-end information flow from A-domain to B-domain and C-domain is suitable to understand the farmers and their livelihood and the development of tailor-made and user friendly agro-advisories. Intensive training of intermediaries is critical in enforcing the adoption of agrometeorological and agroclimatology information and knowledge for improved decision-making.

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