Journal of Agriculture and Rural Development in the Tropics and Subtropics
Vol. 115 No. 2 (2014) 101–110

urn:nbn:de:hebis:34-2014121946895 ISSN: 1612-9830 – journal online: www.jarts.info

Assessing the users' need for a spatial decision support system of smallholder farming in Kenya

Mike Teucher [a,*], Berthold Hornetz [b], Ralph Jätzold [b], Zachariah Mairura [c]

[a] *Department of Spatial and Environmental Science , Faculty of Cartography, Trier University, D-54286 Trier, Germany*
[b] *Department of Spatial and Environmental Science, Faculty of Biogeography, Trier University, D-54286 Trier, Germany*
[c] *Department of Agribusiness and Market Development, Ministry of Agriculture, Nairobi, Kenya*

Abstract

Accurate data of the natural conditions and agricultural systems with a good spatial resolution are a key factor to tackle food insecurity in developing countries. A broad variety of approaches exists to achieve precise data and information about agriculture. One system, especially developed for smallholder agriculture in East Africa, is the Farm Management Handbook of Kenya. It was first published in 1982/83 and fully revised in 2012, now containing 7 volumes. The handbooks contain detailed information on climate, soils, suitable crops and soil care based on scientific research results of the last 30 years. The density of facts leads to time consuming extraction of all necessary information. In this study we analyse the user needs and necessary components of a system for decision support for smallholder farming in Kenya based on a geographical information system (GIS). Required data sources were identified, as well as essential functions of the system. We analysed the results of our survey conducted in 2012 and early 2013 among agricultural officers. The monitoring of user needs and the problem of non-adaptability of an agricultural information system on the level of extension officers in Kenya are the central objectives. The outcomes of the survey suggest the establishment of a decision support tool based on already available open source GIS components. The system should include functionalities to show general information for a specific location and should provide precise recommendations about suitable crops and management options to support agricultural guidance on farm level.

Keywords: agricultural guidance, Farm Management Handbook, geographical information system, land use, small-scale farming

1 Introduction

According to the FAO report on food insecurity, globally, 842 million people are suffering chronic hunger in terms of not getting enough food on a regular basis. Sub-Saharan Africa contributes a proportion of 25 % of undernourished people, which accounts for 13 % of world population. According to the FAO, it is the region with the highest proportion of people suffering from chronic hunger (FAO *et al.*, 2013). Within sub-Saharan countries Kenya recorded 8.4 million undernourished people, 34.8 % of their population in the period from 1990-92. Latest records (2013) indicate 11.0 million undernourished people and a proportion of 25.8 %. The change by -9 percentage points within 21 years shows however only a percentage reduction. The Millennium Development Goals to halve the proportion of people suffering from hunger from 1990 to 2015 will not been reached if the prevailing trend persists (FAO *et al.*, 2013). The reasons for the retardation of this progress

* Corresponding author
Mike Teucher, Dept. of Spatial and Environmental Science, University of Trier, Behringstraße 20, D-54286 Trier, Germany
Email: Mike_Teucher@gmx.de

are diverse and human induced as well as of natural origin. A key factor for hunger reduction apart from good economic growth in general is a successful expansion in agriculture and food production. A growth in agricultural productivity increases the availability of food and reduces the food prices at local markets (FAO *et al.*, 2013).

Approaches to reach this growth and agricultural expansion are versatile and encompass commercial large-scale developments as well as smallholder projects. One of these projects focusing on smallholder developments is the Farm Management Handbook introduced in Kenya by the German International Cooperation (GIZ) in the early 1980s (Jaetzold & Schmidt, 1982). This approach concentrates mainly on the natural conditions and farm management recommendations, but also involves aspects of agribusiness and agricultural administration (Jaetzold *et al.*, 2012). In the recently updated edition all agriculturally important provinces in Kenya received up-to-date information on new crops and crop varieties, including latest available information about resistances and tolerances, as well as descriptions of new techniques and methods for agricultural systems. The handbooks are designed for professional use by agricultural officers and other stakeholders working in the field of smallholder agricultural guidance. Due to the enormous enrichment of information in the second edition the usability of the books decreased on some aspects, for instance the operability of the crop and crop variety lists. It is very time consuming and tedious to find a suitable crop or even crop variety for a specific location and this quest requires experience and special knowledge of the handbooks. Another aspect within the context of usability is the interpretation of maps, due to the limited human perceptive ability of information. Detailed agricultural data are combined with topographic data and multi-layered maps are difficult to read and use.

To solve the drawbacks of usability we are currently developing a computer-based application. Further developments have to be made within the scope of spatially high resolute information for extension officers and decision makers in developing countries. A recent work from the CGIAR Research Program on Climate change, Agriculture and Food Security stated that accurate data about temperature and rainfall with a good spatial distribution are very important for a successful establishment of an agricultural information system (Kadi *et al.*, 2011). The proposed system will be developed as a tool for agricultural officers to have better planning options for site specific measurements. Kadi *et al.* (2011) stated that substantial gains in the scope of agriculture and food security can be reached through the integration of improved climate information. The proposed system will help to improve aspects of food security through the use of state of the art techniques from geoinformatics and agriculture with the help of concrete site specific data.

The system will be established as a spatial decision support system (SDSS). SDSS is a decision support system (DSS) with the ability to visualise and interact with geographical information. Jarupathirum & Zahedi (2007) reviewed SDSS applications within the scope of empirical research studies about the usage of Geographic Information Systems (GIS) combined with DSS and identified similar benefits and handicaps like Keenan (2006):

- Map users make faster decisions than those using tables.
- For a geographic task that does not require examining spatial relationships, using maps is less accurate but provides faster decisions than using tables.
- Performance deteriorates as problem size increases, data aggregation is reduced, and data dispersion is increased.
- GIS maps perform better than paper maps because GIS tools reduce the load on the human cognitive information process.
- Experts are more accurate than novices when using GIS technology to perform geographical tasks.
- Education and training are important for the successful implementation of GIS.

Furthermore, Walker (2002) identified three main pitfalls why decision support-based projects failed. The first issue is defined as non-delivery, where the established tools or systems were not able to meet the user's needs absolutely. Non-adoption occurs when the created system gets redundant after the first or second application through the user. To overcome this problem it is necessary to develop a system which is able to learn through the input of the user or through the utilisation of updated information on a periodical basis. The last pitfall Walker (2002) mentioned is the fact of negative impacts on decision-making processes and quality based on decision support systems.

In this study we identified the user needs and the possible problems of an agricultural information system on the level of agricultural officers in Kenya. To avoid the pitfalls mentioned by Walker (2002) a survey was conducted at the end of 2012 and in early 2013 to answer the elaborate research questions:

(i) What type of decision support system will be adopted by agricultural officers?

(ii) What is the optimal way to integrate a decision support system into the daily routine of the officers?

(iii) What are essential and most important system functions for the officers?

2 Materials and methods

Data were collected during a survey in October 2012 and March 2013. The questionnaire was pretested in September 2012 among five agricultural officers in Kenya and further adjusted to fit the main objectives of the survey. The distribution of the questionnaires was part of several visits to almost all provinces and agricultural important areas in Kenya, originally induced to distribute the recently updated Farm Management Handbooks. During several seminars more than 120 questionnaires were disseminated among agricultural officers, like District Agricultural or Crops Officers. 55 completed questionnaires, mainly from Eastern and Rift Valley Province, were sent back till the end of March 2013. Besides general information, which is essential for every survey, the questionnaire consisted of three fields of interest. To get more reliable ratings the participants were promised to keep all information totally anonymous.

In the first section, questions were stated regarding the agricultural consulting activities and the contact to smallholder farmers. Alongside with information about the frequency of agricultural advices to farmers, the way of getting in contact with farmers and other stakeholders in the focus of land use management was relevant. Furthermore, the main fields of duties in their engagement together with the aforementioned questions delivered useful information about the job situation. To evaluate the needs of a spatial decision support system it is important to get the participants' information about the years of working experience and the satisfaction with the recent workflow (see table 1). Potential hindrances to adopt new innovations are probably the job routine and the level of satisfaction in the current employment. Therefore, the participants were asked to rate the level of contentment in their current employment in the categories "absolutely unsatisfied", "unsatisfied", "neutral", "satisfied" and "absolutely satisfied".

Table 1: *Overview of the questions (reduced to core statements) of the survey in chronological order and type of question classified as multiple response (MR), single response (SR) and essay questions (EQ).*

No.	*Question (reduced to core statements)*	*Type*
1	Frequency of professional advice to smallholder.	SR
2	Mode of transport to smallholder.	MR
3	Area of responsibilities in current employment.	MR
4	Working experience in recent employment.	SR
5	Educational attainment.	SR
6	Involvement of other stakeholders, persons, groups of persons or institutions.	MR
7	Typical workflow of professional advice with smallholders.	EQ
8	Workplace satisfaction in current employment.	SR
9	Willingness to use a computer-aided system as decision support.	SR
10	Experience with computers and computerised systems (e.g. mobile phone, smart phone).	SR
11	Cognisance of computer applications with map and coordinate display functionalities.	SR
12	Usage of map displaying computer applications in the past.	SR
13	Readiness for use of GIS-like computer application for consulting activities as decision support tool.	SR
14	Essential functions for a GIS system to facilitate work with local farmers.	EQ
15	Main sources of information for daily routine.	EQ
16	Knowledge of the Farm Management Handbook of Kenya.	SR
17	Year of birth.	EQ
18	Place of residence (specified in the form of Province, County, District, Division and Location)	EQ
19	Job location	SR
20	Willingness to support project again in later phase.	SR

A second section of the questionnaire concerning the level of education, work experience and typical work flows revealed important insights about the daily routine of the officers. After this general section about the job a more specialised section followed, dealing with the usage and experiences with computerised systems in the course of their consulting activities (see table 1). Therefore, the participants were prompted to classify their experience with computers and computerised systems, for instance, personal computers, mobile phones or smart phones. In addition, questions concerning the willingness to use computer-aided systems as decision support were stated. The participants were asked to rate their willingness on a scale from "hardly conceivable" to "highly conceivable" with an extra position for "no opinion". As core component information about the knowledge of map displaying computer applications should be gained to examine the prevailing propagation of GIS-like systems in agricultural training. Furthermore, the participants were asked to rate the readiness to use a computer application with the functionalities of map and coordinate display for consulting activities. The last question of this section aimed at GIS components. Therefore a definition of GIS was given at the beginning of the questionnaire. Based on the information about GIS the attendants were asked to state essential functionalities of a GIS which would facilitate their work with small-scale farmers.

The final section of the survey consisted of questions concerning the sources of information for their daily work. At the end of the questionnaire some information about the environment of the participants was requested. These questions were helpful to analyse the results of the survey on a geographical basis and to gain data about the age patterns of the officers (see table 1). Another important aspect of the questionnaire was to receive information about the willingness to participate again in a second questionnaire. As Walker (2002) stated with the fact of irrelevance this makes it possible to stay connected to the users of the proposed system.

Statistical analysis and compilation was done using IBM SPSS Statistics 20 (IBM, 2011). Statistical evaluation included calculation of average mean, median, mode, frequency, comparisons on the basis of Kolmogorov-Smirnov test and the calculation of Kendall's Tau (τ) coefficient.

3 Results

To identify the necessity of a SDSS for consulting activities of the agricultural officers, the questionnaire examined the frequency of contact between the officers and smallholder farmers. The majority (56.4 %) of the officers are conducting consulting activities on a daily basis. 29.1 % deal with consulting activities two or three times a week, and 9.1 % give advice to farmers once a week. 3.6 % of the respondents did not answer this question.

69.1 % of the officers have more than 10 years of experience in their recent employment. 16.4 % have more than one but less than five years of experience and are young professionals in the field of agricultural officers (table 2). 14.5 % have already more than five years of experience, but less than 10. More satisfied employees could be more willing to utilise new technologies and methods than unsatisfied workers. 43.6 % rated their contentment at work as "satisfied", and 32.7 % stated to have a neutral attitude towards their situation at work. 20.0 % of the surveyed people are absolutely satisfied with their workflow and 1.8 % did not complete this question or are unsatisfied in their recent employment.

Almost two-third (65.5 %) of the surveyed officers declared that it is highly conceivable for them to use a computer-aided system as decision support. 23.6 % marked that it would be conceivable for them, and 3.6 % stated that it is hardly conceivable to use such a system for their workflow. 3.6 % of the participants had no opinion about the usage of a computer-aided system as decision support in their job. Knowing this result

Table 2: *Contingency table of years of experience and willingness to use a computer-based system in % (n=55)*

Years of work experience in recent employment	*Willingness to use computer application with GIS functionalities?*					*total*
	no	*hardly imaginable*	*depends on quality and usability*	*yes*	*no opinion*	
more than 1, but less than 5 years	5.5	0	7.3	3.6	0	16.4
more than 5, but less than 10 years	1.7	0	5.5	7.3	0	14.5
more than 10 years	12.7	7.3	21.8	21.8	5.5	69.1
total	20	7.3	34.5	32.7	5.5	100

it is essential to obtain more information on the average experience with computers and computerised systems. Especially for the development and establishment of a computer-based SDSS it is important to know what level of complexity is sufferable for the potential user of the system. 40.0 % of all respondents have above-average experience with computers and 21.8 % evaluated their experience as average determined by one or two times of monthly use and as part of professional training. 16.4 % rated their experience in the category "low experience" with less than five times of computer use in their lives. 10.9 % had no experience at all with computerised systems. The remaining 10.9 % of the respondents think to have an outstanding experience with computers as part of their daily workflow. From the above-mentioned 89.1 % of the respondents that are experienced with computers 51.1 % do not know computer applications with the functionality of maps and coordinate display; the rest of the respondents (48.9 %) do. Out of the latter group 83.3 % used such functionalities in the past once or more than once and only 16.7 % are still using such applications on a regular basis.

Based on this question about the experience and knowledge of computers and computerised systems with map-displaying functionalities the participants were requested to classify their willingness to use a computer application with GIS functionalities for their consulting activities as a decision support tool. From the sampled agricultural officers almost one third (32.7 %) stated that such an usage would be highly conceivable for their consulting activities, another third (34.5 %) stated that it would be easily conceivable for them to use such a system, however depending on the usability and quality of it. 20.0 % stated that they would not use a GIS-like computer application in their consulting activities. For 7.3 % it would be hardly imaginable and 5.5 % did not answer this question (see also table 2). For those 74.5 % of the respondents who stated that they would at least think about the usage of a GIS system the concrete needs and functions of such a system were requested. The most often requested functionality (60.0 %) was to display suitable crops and varieties for specific locations. The second most common function mentioned was the opportunity to offer general, non-environmental information for a specific location, like administrative information and how to connect farmers to markets (51.1 %). The third preferred function was the feature to show climatic data with 33.3 %. Another 31.1 % of the participants requested an option to locate farmers and other specific agricultural related places and 28.9 % of all participants wished to have a functionality to show specific values for agronomic practices and trainings. 26.7 % asked for a functionality to monitor production activities and value addition programmes as well as showing data about the agroecological zones. 22.2 % of all respondents recommend an opportunity to show soil related information. The possibility to present data concerning altitudes was found in 17.8 % of all answers. Merely 11.1 % and 2.2 % asked for a way to connect farmers with each other and to show forest cover in a specific region (see figure 1).

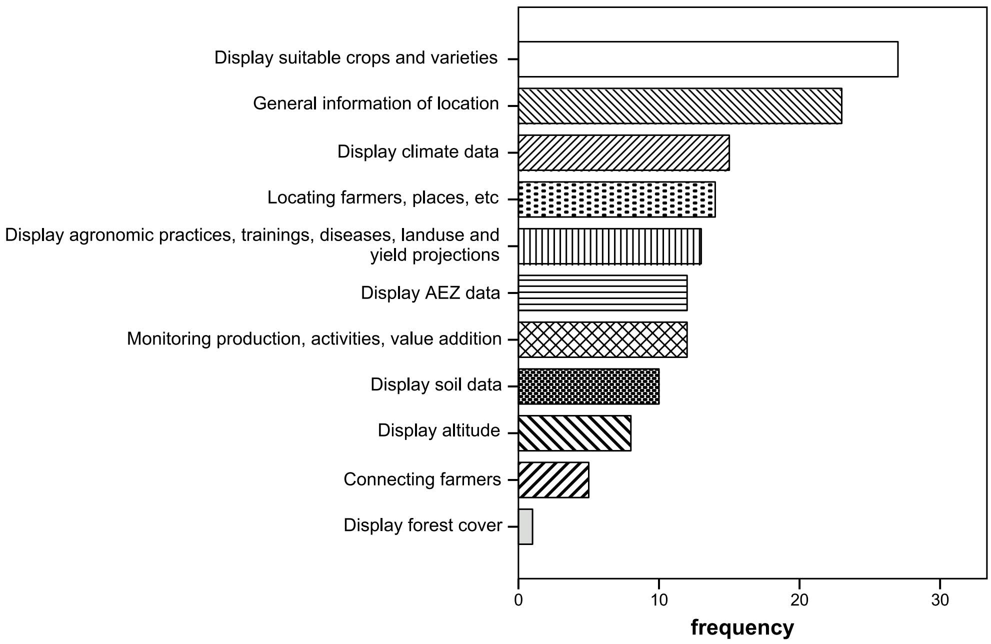

Fig. 1: *Preferred essential functions for the proposed GIS system (N=140)*

To identify possible hindrances in the usage of computer-aided systems in consulting activities, additional analyses were done correlating the age of the officers and the experience in the job to the willingness to use a computer-aided system as well as on the willingness to use a computer application with map displaying functionalities like a GIS (see table 2). The statistical results of the Kolmogorov-Smirnov test showed that there is neither a significant influence of the age of the respondent on the usage of a computer-aided system (p=0.999), nor on the usage of a computer application with map displaying functionalities (p=0.153). Years of working experience neither had a significant influence on the possible use of the system, as proved by the calculation of Kendall's Tau coefficient ($\tau = 0.581$).

4 Discussion

The results revealed that the majority of the officers conduct consulting activities on a daily basis (56.4 %) and most officers perform mainly field work (54.1 %). Therefore, it is necessary for them to have fast access to all relevant information. Taking into account the fact that working with the printed Farm Management Handbooks is very tedious, an easier flow of information would facilitate their work. Two third of the respondents indicated their willingness to use a computer-based information system; such a system could bring a lot of benefits for their daily workflow. Especially to get in touch with farmers, a computer-based system would facilitate their work in terms of providing printable outputs like maps or tables to visualise the target group specific information. Such outputs are more comfortable than whole reports or less user-friendly formatted outputs from a webpage, and are also easier to send to other stakeholders.

Based on the results that over 70 % of the respondents stated they have average and above average experience with computers and almost half (48.9 %) of the surveyed people do have knowledge of map displaying computer applications, the establishment of a SDSS could be envisaged. Especially as part of consulting activities for smallholder farmers, the officers could prepare specific maps and lists of suitable crops for a certain location. The use of maps can be a powerful tool for the farmers to get a precise description of the natural conditions of their environment and all suitable farming opportunities. This could lead to a win-win situation for both officer and farmer. The officers can reduce their preparation time and will have more time for guidance of the farmers. The farmers could increase their food security status at the farm, by optimising their agricultural systems due to site specific recommendations and information received.

Potential hindrances to adopt new innovations at the level of the officers are possibly the job routine and the level of satisfaction with the current employment. But as 67.2 % of the participants stated that it is conceivable to use a SDSS for consulting activities and 76.4 % of all participants showed neutral or satisfied attitude towards their recent workflow, the proposed SDSS could be successfully introduced. Satisfaction in the current employment is closely tied to the duration of the employment and the experience that employees gathered through their job. However, the survey indicated that neither the years of experience, nor the age of the participants showed negative impacts on the possible usage of a computer-aided system or a GIS-like system as decision support. This shows that the majority of the agricultural officers are well trained and ready to advance in their jobs.

In the survey there was one particular question that allowed stating preferred essential functions. It should be clear that the results of a question in form of a wish list can never reflect all facets for everyone's contentment. But surprisingly, the majority of participants wrote down similar desired functionalities for the system. The most important function would be to display most suitable crops and crop varieties together with the opportunity to visualise climatic data and general information for a specific location. Other desired functions like the localisation of farmers, the monitoring of production activities or planning of agronomic practices and trainings are impossible to incorporate in a SDSS at the moment, due to a lack of essential base data and geodata. But with the help of a SDSS and the most wanted functionalities about crops and climatic data a more effective operative network between farmers and officers could be established, based on bilateral inputs and communication, and, consequently, the necessary base data and geodata could be produced. These findings are in accordance with the recommendations of Kadi *et al.* (2011) on accurate and spatially high-resolution geodata, but contradict with the recent developments of most of the information systems in agriculture. The majority of existing systems, especially in developed countries are based on large scale strategies and a high level of mechanisation (Ortmann, 2000). These systems are predestined for the use at large scale farms in terms of machine-aided harvesting, fertiliser application, automated driving or in the focus of yield estimation based on remote sensing (Lowenberg-DeBoer, 1999; Nash *et al.*, 2009; Bill *et al.*, 2012). Due to the meagre income of most smallholder farmers and the average farm size (Jaetzold *et al.*, 2012), a high-tech approach is not qualified as decision support for smallholder farmers. At this stage, there is no working information system on agricultural parameters and data available for the whole country of Kenya. There are a few systems available, but most of them, e.g. the National Farmers Information Service (NAFIS) or the Kenya Agricultural Information Network (KAiNet), are designed as information webpage or question and answer panels (KAINet, 2014; NAFIS, 2014).

Whereas the majority of the items covered special facets and aspects of a SDSS, there were some related to the possible type of SDSS, which is the most important research question. According to a report from World Bank, African Development Bank and African Union about the application of information and communication technologies in agriculture most systems in eAgriculture are only valuable if the users find the systems easy to use and reliable (Yonazi *et al.*, 2012). Therefore, in general the integration of new approaches in already existing systems is recommended, e.g. the dissemination of new approaches through existing communication services like mobile phones or already available webpages. Furthermore, the technology has to be cheap, available and should have a functionality for off-line operation (Yonazi *et al.*, 2012). The idea of a spatial decision support system on the basis of a geographical information system was preferred and accepted by two-third of the participants, which highlights the importance of spatial datasets for consulting activities.

Frequently stated in literature in regard of eAgriculture approaches is the use of mobile phones (Tenywa *et al.*, 2008; Gakuru *et al.*, 2009; Richardson, 2009). The usage of mobile devices in Kenya increased rapidly within the last decade. Whereas in the year 2001 only 1.9 mobile cellular subscriptions per 100 people were recorded, this value was 67.5 in 2011, which is an increase by the factor of 36 (The World Bank, 2014). The use of mobile phones in eAgriculture and their potential is well known and getting more and more important for improving livelihoods also in Kenya. Therefore, it is not surprising that almost 95 % of the population has access to mobile coverage. The main problem for mobile phone use and the required infrastructure is the issue of improving and maintaining the public grid electricity supply to provide power for network towers. Based on the findings from a study performed by GSMA and Safaricom in 2012 (Shulist, 2012) the use of mobile phones for consulting activities in smallholder agriculture is not conceivable, due to problems of electricity and network coverage in rural areas. Mobile services are available in 38 % of the country, but most of the working network towers are located in the southern and western urban areas of Kenya (Shulist, 2012). According to iHub Research and Research Solutions Africa (2012) over 60 % of all Kenyan households have electricity. The government made substantial progress in this issue within the last five years, but coverage and reliability of electricity is still low (Shulist, 2012). Another problem for a possible usage of mobile phones is the type of phone and their present distribution. 53 % of Kenyan mobile phones are categorised as basic type. This basic type incorporates functions like making a phone call, writing messages, accessing information via Unstructured Supplementary Service Data (USSD), but does not support the use of the World Wide Web, has no GPS functionality to show the exact position, and the most important handicap is the lack of displaying geodata in form of maps and tables. In future the use of mobile phones for complex and specific tasks in the course of agricultural related consulting activities is imaginable, but at the moment, due to the above-mentioned circumstances, the required data volume and low rate of transmission hamper a successful development.

As Kadi *et al.* (2011) pointed out accurate data on temperature and rainfall with a good spatial distribution are very important for a successful establishment of an agricultural information system. Based on the requested functionalities and the stated willingness to use a SDSS for consulting activities the most promising approach for Kenya to have a successful introduction of such a system is its development on the basis of already existing software programmes. This corresponds with findings of Jarupathirum & Zahedi (2007), and Keenan (2006) who underline the use of already operative GIS components as part of a DSS. Principles and techniques for building an agricultural SDSS to support smallholder farmers in Kenya should be based on common SDSS-creation directives, which are often mentioned and defined in literature (Malczewski, 1999; Bakker-Dhaliwal, 2001; Keenan, 2006; Mir & Quadri, 2009; Sugumaran & DeGroote, 2011). However, the number of main components of a SDSS varies largely in literature. In the planned agricultural SDSS the component of Database Management (DBMS) will be allocated by a relational database management system (RDBMS) on the basis of public domain programming. The benefits of relational databases are well documented and, furthermore, well suited for the use in other systems or with programming languages like SQL (Nyerges, 1997; Bernhardsen, 1999; Longley *et al.*, 1999). The RDBMS will be connected to the GIS software Quantum GIS, which covers the components of Knowledge-Based Management

Subsystem (KBMS) and the User Interface Subsystem like defined by Mir & Quadri (2009). Quantum GIS is a geographic information system written in the programming language C++ and is based on the use of the Qt class library (Suzuki, 2011). It combines viewing and processing of vector and raster data through the use of several extensions, which could be easily installed and used (Sherman, 2012).

Therefore, QGIS could be well suited for providing the basic framework for the implementation and integration of further model management components or even stakeholder components. The proposed system enables the integration of methods and theories for evaluation and calculation of agronomic parameters, like calculations of rainfall probabilities based on long-term measurements, the computations of start and length of growing periods during the year on the basis of WATBAL results ("WATer BALance"; Müller, 2005), or the calculation of seasonally differentiated yield potentials by the use of the crop simulation program MARCROP ("MARginal CROPping") and the ENSO ("El Nino Southern Oscillation") module (detailed information can be found in Hornetz *et al.* (2001).

In particular the last-mentioned methods were specially developed for their use in the semi-arid zones of Kenya and provide a solid basis for precise recommendations concerning crop selection, soil care provision, crop yield estimation, and as such enhance food-security situation. The described principles and techniques for development mainly arise from open source projects. The possible benefits of open source components were often discussed in literature and incorporate three key issues (Longley *et al.*, 1999; Steiniger & Hunter, 2013). The source code of the software is under public domain and, therefore, easily adjustable and expandable. Most of the applications are platform-independent and, hence, they are reusable in various operating systems. The operation and maintenance are independent from software producers and in most cases there are no license fees. Other benefits of open source components are the well documented capabilities and the fact that a strong community exists (Sherman, 2012). Key points of the proposed SDSS are the following:

- Information about the natural conditions precisely to one location;
- Selection of suitable crop varieties derived from the environmental information of the location segmented by growing periods and classified according to their potential;
- Opportunity of printing the information in a tabular way or as maps;
- Integration of data derived from global positioning devices as a post-processing service after capturing the data in the field.

5 Conclusion

Summarising the survey and consequential findings the introduction of a computer-based SDSS and respective training for consulting activities of agricultural officers in Kenya could lead to an essential improvement of the livelihood of the rural smallholder farmers and could contribute crucially to food security situation in Kenya, especially in the semi-arid zones. As already mentioned in the text we are in the development phase of a SDSS to support smallholder farming. To achieve all necessary goals and to incorporate the findings of the survey, we work in close cooperation with the GIZ and the Ministry of Agriculture of Kenya as they will be the institutions for training and qualification of the officers when the system will be established. Once all features are implemented and the system passes through testing and validation phase qualified employees of the GIZ and Ministry of Agriculture should be trained, who can disseminate the system and have the know-how to operate it.

Acknowledgement

We thank the German International Cooperation (GIZ) and the Ministry of Agriculture, Kenya, for the dissemination of the questionnaire and the use of their infrastructure during our field trips. We are grateful for critical comments and valuable recommendations on a draft version of this manuscript by two anonymous referees.

References

Bakker-Dhaliwal, R. (2001). Decision support systems (DSS): information technology in a changing world. International Rice Research Notes 26. Pp. 5-12.

Bernhardsen, T. (1999). *Geographic information systems. An introduction. 2. Ed.*. Wiley, New York.

Bill, R., Nash, E. & Grenzdörffer, G. (2012). GIS in Agriculture. In W. Kresse, & D. M. Danko (Eds.), *Springer handbook of geographic information* (pp. 461–476). Springer, Berlin, Heidelberg, Germany.

FAO, IFAD & WFP (2013). *The state of food insecurity in the world 2013.The multiple dimensions of food security*. FAO, Rome.

Gakuru, M., Winters, K. & Stepman, F. (2009). Inventory of innovative farmer advisory services using ICTs. Forum for Agricultural Research in Africa (FARA). URL http://www.fara-africa.org/media/uploads/library/docs/fara_publications/Innovative_Farmer_Advisory_Systems.pdf last accessed 06-30-2014.

Hornetz, B., Shisanya, C. A. & Gitonga, N. M. (2001). Crop water relationship and thermal adaptation of kathika beans (*Phaseolus vulgaris* L.) and green grams (*Vigna radiata* L. Wilczek) with special reference to temporal patterns of potential growth in the drylands of SE Kenya. *Journal of Arid Environments*, 48, 591–601.

IBM (2011). *IBM SPSS Statistics for Windows, Version 20.0*. IBM Corp., Armonk, NY.

iHub Research and Research Solutions Africa (2012). Mobile usage at the base of the pyramid in Kenya. URL http://www.infodev.org/en/TopicPublications.34.html last accessed 06-30-2014.

Jaetzold, R., Hornetz, B., Shisanya, C. A. & Schmidt, H. (2012). *Farm management handbook of Kenya. Volume II: Natural conditions and farm management information Part C: East Kenya, Subpart C2: Coast Province. 2. Ed.*. Ministry of Agriculture, Nairobi.

Jaetzold, R. & Schmidt, H. (1982). *Farm management handbook of Kenya - Vol. II: Natural conditions and farm management information*. Rossdorf.

Jarupathirum, S. & Zahedi, F. M. (2007). Exploring the influence of perceptual factors in the success of web-based spatial DSS. *Decision Support Systems*, 43, 933–951.

Kadi, M., Njau, L. N., Mwikya, J. & Kamga, A. (2011). The state of climate information services for agriculture and food security in East African Countries. Working Paper No. 5. CGIAR research program on climate change, agriculture and food security (CCAFS). Copenhagen, Denmark. URL http://www.ccafs.cgiar.org last accessed 10-28-2013.

KAINet (2014). Kenya Agricultural Information Network. URL http://www.kainet.or.ke last accessed: 07-04-2014.

Keenan, P. B. (2006). Spatial decision support systems: A coming of age. *Control and Cybernetics*, 35, 9–27.

Longley, P., Goodchild, M. F., Maguire, D. J. & Rhind, D. W. (1999). *Geographical information systems. Volume 1*. John Wiley, New York.

Lowenberg-DeBoer, J. (1999). Risk management potential of precision farming technologies. *Journal of Agricultural and Applied Economics*, 31 (2), 275–285.

Malczewski, J. (1999). *GIS and multicriteria decision analysis*. John Wiley, New York.

Mir, S. A. & Quadri, S. M. (2009). Decision support systems: concepts, progress and issues – A review. In E. Lichtfous (Ed.), *Climate change, intercropping, pest control and beneficial microorganisms* (pp. 373–399). Springer. Dordrecht, Netherlands.

Müller, M. (2005). Benutzer-Handbuch für WATBAL 2003. University of Trier, unpublished.

NAFIS (2014). National Farmers Information Service (NAFIS). URL http://www.nafis.go.ke last accessed 07-04-2014.

Nash, E., Korduan, P. & Bill, R. (2009). Applications of open geospatial web services in precision agriculture: a review. *Precision Agriculture*, 10, 546–560.

Nyerges, T. L. (1997). UNIT 11 - Spatial objects and database models. In M. F. Goodchild, & K. K. Kemp (Eds.), *NCGIA Core Curriculum in GIS*. University of California, Santa Barbara, USA.

Ortmann, G. F. (2000). Use of information technology in South African agriculture. *Agrekon*, 39, 26–35.

Richardson, D. (2009). How can agricultural extension best harness ICTs to improve rural livelihoods in developing countries? In E. Gelb, & A. Offer (Eds.), *ICT in agriculture: perspectives of technological innovation*. The Hebrew University of Jerusalem Center for Agricultural Economic Research. Rehovot, Israel.

Sherman, G. E. (2012). *The geospatial desktop: Open source GIS & mapping*. Locate Press, Williams Lake, B.C.

Shulist, J. (2012). Safaricom - Kenya - feasibility study. GSMA Community power from mobile. IFC World Bank Group. GSMA. URL http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2013/02/Safaricom-Feasibility-Study.pdf last accessed 06-30-2014.

Steiniger, S. & Hunter, A. J. S. (2013). The 2012 free and open source GIS software map – A guide to facilitate research, development, and adoption. *Computers, Environment and Urban Systems*, 39, 136–150.

Sugumaran, R. & DeGroote, J. (2011). *Spatial decision support systems. Principles and practices*. CRC Press, Boca Raton.

Suzuki, T. (2011). Modular Class Library — Qt: A cross-platform application and UI framework. Nokia. URL https://events.linuxfoundation.org/images/stories/pdf/lcjp2012_suzuki.pdf?a last accessed 06-30-2014.

Tenywa, M. M., Fungo, B. & Tumusiime, F. (2008). ICT in agricultural education, research, and outreach in Uganda. In T. Nagatsuka, & S. Ninomiya (Eds.), *World conference on agricultural information and IT, IAALD AFITA WCCA 200* (pp. 841–848). Tokyo University of Agriculture, Tokyo, Japan.

The World Bank (2014). World Databank: Mobile cellular subscriptions (per 100 people). URL http://data.worldbank.org/country/kenya last accessed 11-26-2014.

Walker, D. H. (2002). Decision support, learning and rural resource management. *Agricultural Systems*, 73, 113–127.

Yonazi, E., Kelly, T. H. & Blackman, C. (2012). The transformational use of information and communication technologies in Africa. The World Bank, African Development Bank and African Union. URL http://go.worldbank.org/CXS4GFJDE0 last accessed 06-30-2014.