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PREFACE

Information technology is an everyday means that is found in all walks of life today. This is also true for almost all areas of agricultural management. The aim of this Journal is to improve scientific knowledge dissemination and innovation process in the agri-food sector. The Journal of Agricultural Informatics has been established in 2009 by the HAAI within a project of the Hungarian National Development Plan Framework. The peer-reviewed journal is operating with international editorial and advisory board supported by the EFITA (European Federation for Information Technology in Agriculture Food and the Environment).

Agricultural informatics serves not only the development of the management systems of the industry but also obtaining and publicising information on production, organisation and the market for the producer.

Technologies into network based business systems built on co-operation will ensure up-to-date production and supply in food-industry. The sector-level approach and the traceability of processed agricultural products both require the application of up-to-date information technology by actors of domestic and international markets alike.

This journal serves the publication as well as familiarization the results and findings of research, development and application in the field of agricultural informatics to a wide public. It also wishes to provide a forum to the results of the doctoral (Ph.D) theses prepared in the field of agricultural informatics. Opportunities for information technology are forever increasing, they are also becoming more and more complex and their up-to-date knowledge and utilisation mean a serious competitive advantage.

These are some of the most important reasons for bringing this journal to life. The journal “Agricultural Informatics” wishes to enhance knowledge in the field of informatics, to familiarise its readers with the advantages of using the Internet and also to set up a forum for the introduction of their application and improvement.

The editorial board of the journal consists of professionals engaged in dealing with informatics in higher education, economists and staff from agricultural research institutions, who can only hope that there will be a demand for submitting contributions to this journal and at the same time there will also be interest shown toward its publications.

Prof. Dr. Miklós Herdon

Chair of the Editorial Board

Content

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Analyzing the value of the residue of crops grown on arable land with stochastic optimization

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A B S T R A C T

Determining the value of the residues of crops grown on arable land is a non-trivial task, depending much on how it is defined. In this paper the value of residues is considered to be the savings achieved on the total expense of artificial fertilizer distribution by returning the residues into the soil. A general linear programming approach is presented to obtain optimal artificial fertilizer allocation. Since the amount of artificial fertilizers required depends on uncertain inputs Monte Carlo simulation is applied in conjunction with linear programming to solve the arising stochastic optimization problem. The input data, such as the national average yield, specific amounts of nutrients required by crops to achieve the national average yield and publicly available details of different artificial fertilizer products are specific to Hungary, but the mathematical model presented is general in nature. Simulations are executed for some of the major crops, including wheat, corn, sunflower and rape. The distribution of savings achieved on returning their residues to the soil is provided at the end of the paper for further use.

1. Introduction

The value of crop residues can be defined in many ways, and depending on this definition different qualitative or quantitative measures can be determined. In this paper the definition is chosen to be the savings achieved on artificial fertilizing caused by the amount of nutrients returned into the soil, which can be described with a quantitative measure, namely the difference of the total expense of the fertilizing process with and without returning crop residues to the soil. Determining the value of crop residues this way used to be an elaborate and complex task, but its results are extremely useful – especially in financial decision support. It is required to answer common questions such as whether crop residue should be collected and sold or returned to the soil instead.

The planning of artificial fertilizer allocation of different fields is a six-step process. First, the expected yield (in kg/m^2) of the crop sowed into a field has to be decided. Next, the amount of nutrients – nitrogen (N), phosphorus (P) and potassium (K) – stored in the field are measured. The third step is to determine the specific nutrient requirements (kg of nutrient / kg of yield) of the crop. After this, the quantified nutrient requirements are calculated (in kg/m^2). The fifth step is to perform the correction of the quantified nutrient requirements, and lastly the optimal amounts of the different artificial fertilizer products are allocated to the field (eds Nábrádi, Pupos & Takácsné,2007).

The methods of operations research are scientific approaches to decision making, seeking to best design and operate systems under conditions, usually with the help of mathematical models. Such models consist of three components: objective function(s), decision variables and constraints. Optimization models seek to find the values of the decision variables that optimize (maximize or minimize) an objective function so that the given constraints are satisfied. If the objective function and the constraints can be written as linear combinations of the decision variables the optimization problem can be solved with linear programming (Winston & Goldberg, 2004). To this day many textbooks on agricultural management teach only heuristic approaches to solve such problems, including the allocation of artificial fertilizer. By applying these approaches one is unlikely to find an optimal solution - even though simple linear programs could be used instead to obtain *optimal*

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allocations, they still lack public awareness in Hungary (even in the ranks of professional agricultural engineers). Since the 85-95% of the total expense of artificial fertilizing comes from the cost of the artificial fertilizer itself the optimal choice of products is unquestionably crucial (eds Nábrádi, Pupos & Takácsné, 2007).

There are important but difficultly quantifiable factors which have to be taken into consideration throughout the planning of artificial fertilizer allocation though. These factors are the amount of nutrients stored in the soil and the required amount of nutrients of a crop to achieve an expected yield. Their values are usually estimated based on lower and upper bounds provided in textbooks and professional experience. In a mathematical point of view they should be represented with random variables. Random variables take on specific values with specific probabilities – these value-probability pairs are described by probability distributions (Durrett, 2013). By including random variables we include uncertainty into the optimization model, thus arrive at a stochastic programming problem (King & Wallace, 2012). A common solution approach is simulation – we generate scenarios by taking samples from the probability distributions and solve the original problem for each scenario (Prékopa, 1995). One such sampling method is the Monte Carlo method – among all the numerical methods that rely on n-point evaluations in an m-dimensional space the absolute error of the Monte Carlo approximation decreases fastest, which gives the method an edge as the size of the problem increases (Fishman, 1996).

The application of linear programming or Monte Carlo simulation is not an extraneous concept in agricultural sciences either. Experimenting and prototyping are useful tools, but they are not able to provide on-time answers as opposed to simulation methods. A four-step iterative process is proposed in (Bergez, Colbach, Crespo, Garcia, Jeuffroy, Justes, Loyce, Munier-Jolain & Sadok, 2010) to design crop management systems with simulation. First a seed (consisting of strategies or decision rules) must be defined that is going to be used to generate crop management plans. In the second stage the simulation of such plans is executed. The third step involves evaluating the simulated plans, and lastly the interesting crop management options are selected and/or the seed is improved, starting a new iteration. Aldeseit used a linear programming model to determine least-cost synthetic fertilizer combinations and showed how important the application of linear programming might be (Aldeseit, 2014). A general mixed integer programming (MIP) model is introduced in (Hansson, Svensson, Hallefält & Diedrichs, 1999) that is capable of optimizing the amount of fertilizing products that have to be applied in each year of a cutting cycle of energy crops. Their model lacks the presence of uncertainty though, and it does not consider discretizing the total area into fields, which may affect optimal allocations. The model of Mínguez, Romero and Domingo approaches fertilizer allocation differently. Their model does not require nutrient requirements to be satisfied by all means – it views these requirements only as targets that should be achieved and penalizes the differences, allowing a more flexible and realistic specification of lower and upper limits of nutrients (Mínguez, Romero & Domingo, 1988). A possible application of simulation in conjunction with linear programming is shown to maximize the nutrient contents of compost manure prepared using pig dung, buffalo dung, green manure and concentrated super phosphate in (Minh, Ranamukhaarachchi & Jayasuriya, 2007). Simulation and linear programming are also applied in soil erosion control (Segarra, Kramer & Taylor, 1985), irrigation management (Li, Lu, He and Shi, 2014) and urban water management (Zhu, Marques & Lund, 2005), working schedule planning (Matsui, Inoue, Matsushita, Yamada, Yamamoto & Sumigama, 2005), organic farming risk management (Lauwers, Decock, Dewit & Wauters, 2010), etc.

2. Material and method

To model the total expense of fertilizing with and without returning crop residues to the soil Monte Carlo simulation is applied in conjunction with linear programming. First the mathematical model involved in Monte Carlo simulation is described in details, followed by the optimization model. Data is provided only for wheat, corn, sunflower and rape, but the mathematical models presented are independent from the data and can be extended easily.

2.1. Monte Carlo model

The Monte Carlo model is similar in nature to that of the four-step process proposed in (Bergez, Colbach, Crespo, Garcia, Jeuffroy, Justes, Loyce, Munier-Jolain & Sadok, 2010). The seed used for generating scenarios is defined as follows. It is assumed that the hypothetical total area (denoted with *TA*) involved in the calculations consists of 10,000,000 square meters (1,000 hectares) – an area of such magnitude ensures statistically representative results. The savings are simulated for each crop independently - it is also assumed that in every simulation only the kind of crop that is under simulation has been harvested from the whole area. The crops involved in the simulation are presented as the set *C*, such that

$$C = \{wheat, corn, sunflower, rape\}. \tag{1}$$

The total area is then divided into $n = |C \backslash \{HC\}|$ fields – one field for the next generation of each different crop other than the one previously harvested (denoted with HC), in accordance with the crop rotation principle. To obtain general results the area of the fields (denoted with A_i) should vary between 0 m^2 and 10,000,000 m^2, but the sum of their expected values should equal the total area. Such partitioning can be achieved by using PERT distributions (Vose, 2008). The expected value of a PERT distribution is calculated as

$$\boldsymbol{E} = \frac{a + 4 \times m + b}{6}, \tag{2}$$

where *a* and *b* are the lower and upper bounds, and *m* is the most likely value (Malcolm, Roseboom & Clark, 1959). The *a* and *b* parameters are 0 and *TA* respectively, but the *m* parameter has to be specified. To obtain PERT distributions with these lower and upper limits, and expected values summing to the total area we have

$$\frac{TA}{n} = \frac{0 + 4 \times m + TA}{6}, \tag{3}$$

from which we get that

$$m = \frac{\frac{TA}{n} \times 6 - TA}{4}. \tag{4}$$

Another constraint is that the sum of the areas of all the fields must equal the total area, which can be enforced as follows:

$$A_i \sim \min\left(PERT(0, m, TA), TA - \sum_{k=0}^{i-1} A_k\right), \text{where} \quad i \in \{1,2, \ldots n\} \text{ and } A_0 = 0. \tag{5}$$

This constraint biases A_2, A_3, …, A_n though. To lessen the bias effects the values of $A_1, A_2, \ldots, A_n$ are permuted randomly in every iteration of the simulation. The permuted areas are then always assigned to the different crops in a linear order.

The yield of field *i* can be defined as

$$Y_i = \iint_{F_i} u(x, y)\, dF_i, \tag{6}$$

where F_i represents the boundaries of field i, and $u(x, y)$ is the function describing the yield of field *i* in its specific points. A simulation of fields as described in (5) does not specify the boundaries, only the area of each field. Even if the boundaries would be specified $u(x, y)$ would be a multivariate probability density function that had to be estimated. To simplify the problem fields are discretized into one dimension, namely into sequences of squared meters. This way the estimation problem boils down to fitting univariate probability distributions to historical yield data. The lower and upper limits of the national average yield are provided in Table 1. The average yield, combined with the area of the previously described fields can be used to calculate the amount of nutrients returned by the crop residues to each field. The lower yield limits (LYL) and upper yield limits (UYL) are based on historical data from 2004 to 2014 stored by the Hungarian Central Statistical Office.

Table 1. Lower and upper limits of national average yield

Harvested Crop (HC)	Lower (LYL) [kg/m^2]	Upper (UYL) [kg/m^2]
Wheat	0.4	0.6
Corn	0.4	0.8
Sunflower	0.2	0.26
Rape	0.2	0.3

It is acceptable to assume that the average yield of the different crops is uniformly distributed between these limits – the Kolmogorov-Smirnov p-values are 0.799, 0.1561, 0.799 and 0.871, respectively. That said, the yield of the k^{th} square meter in field i (denoted with $y_{i,k}$) is described formally as

$$y_{i,k} \sim U\left(LYL_{HC_i}, UYL_{HC_i}\right), \text{where} \quad k \in \{1,2,\dots,A_i\}, \text{and} \tag{7}$$

the HC_i index denotes the crop that has been harvested from field i. The yield of field i (denoted with Y_i) is the sum of the yield of each square meter within said field. Since it is assumed that the yields of the square meters are independent and identically distributed, and the number of square meters in each field is expected to be very high, the yield of field i can be approximated with a normal distribution (in accordance with the central limit theorem) as follows:

$$Y_i = \sum_{k=1}^{A_i} y_{i,k} \sim N\left(A_i \times \boldsymbol{E}(y_{i,1}), \sqrt{A_i \times \boldsymbol{Var}(y_{i,1})}\right) = \\ = N\left(A_i \times \frac{LYL_{HC_i} + UYL_{HC_i}}{2}, \sqrt{A_i \times \frac{1}{12}\left(UYL_{HC_i} - LYL_{HC_i}\right)^2}\right), \tag{8}$$

where ***E*** is the expected value operator and ***Var*** is the variance operator. The ratio of nutrients released from crop residue is provided in Table 2. These values are also essential in calculating the total amount of nutrients returned into each field.

Table 2. Ratio of nutrients released from 1 kg of crop residue (Sebestyén, Baranyai & Boldis 1983)

Harvested Crop	Returned nutrient ratio (RNR)		
	N	P	K
Wheat	0.005	0.003	0.008
Corn	0.006	0.002	0.006
Sunflower	0.008	0.003	0.001
Rape	0.004	0.002	0.005

The amount returned from nutrient j into field i is denoted with R_i^j and equals the product of the yield of field i (denoted with Y_i) and the returned ratio of nutrient j from the harvested crop on field i (denoted with $RNR_{HC_i}^j$), formally:

$$R_i^j = Y_i \times RNR_{HC_i}^j, \text{where} \quad j \in \{N, P, K\}. \tag{9}$$

It is assumed that each generation of crop fully exhausts the soil, meaning that only R_i^j is available for the next generation – the rest has to be supplied with artificial fertilizer.

The amount of nutrients required by a specific crop to achieve the national average yield varies between certain limits, as shown in Table 3.

Table 3. Nutrient amount ranges required for achieving the national average yield (eds Bocz, Késmárki, Kováts, Ruzsányi and Szabó, 1992)

Planned Crop (PC)	Nutrient requirement [kg/m^2]					
	N		P		K	
	Lower (LNL^N)	Upper (UNL^N)	Lower (LNL^P)	Upper (UNL^P)	Lower (LNL^K)	Upper (UNL^K)
Wheat	0.0135	0.0135	0.0068	0.0068	0.0100	0.0100
Corn	0.0120	0.0200	0.0066	0.0204	0.0066	0.0204
Sunflower	0.0030	0.0080	0.0040	0.0120	0.0080	0.0140
Rape	0.0050	0.0110	0.0070	0.0080	0.0080	0.0100

Mathematically the amount required from nutrient j in the k^{th} square meter of field i is a random variable, denoted with $X_{i,k}^j$. It is assumed that the values of these random variables are independently and identically uniformly distributed between the aforementioned lower and upper limits. The lower nutrient limit from nutrient j for a square meter of field i is denoted with $LNL_{PC_i}^j$, where the PC_i index indicates the planned crop in field i in next year's crop rotation plan. $UNL_{PC_i}^j$ denotes the upper nutrient limit in a similar way. Formally,

$$X_{i,k}^j \sim U\left(LNL_{PC_i}^j, UNL_{PC_i}^j\right). \tag{10}$$

The nutrient requirement of field i from nutrient j, denoted with NR_i^j, can be calculated by taking the sum of the nutrient requirement of every square meter in that field. Since it is assumed that every $X_{i,k}^j$ is independent and identically distributed the central limit theorem is applicable:

$$NR_i^j = \sum_{k=1}^{A_i} X_{i,k}^j \sim N\left(A_i \times \boldsymbol{E}\left(X_{i,1}^j\right), \sqrt{A_i \times \boldsymbol{Var}\left(X_{i,1}^j\right)}\right) = \\ = N\left(A_i \times \frac{LNL_{PC_i}^j + UNL_{PC_i}^j}{2}, \sqrt{A_i \times \frac{1}{12}\left(UNL_{PC_i}^j - LNL_{PC_i}^j\right)^2}\right). \tag{11}$$

At this point the seed for generating scenarios is fully defined – based on these rules the second step (the simulation of scenarios) can be executed. The third step of the process is the evaluation of each scenario. To get the value of the crop residues the total expense of fertilizing with and without returning the residues to the soil has to be determined - their difference is the actual amount saved on fertilizing. To obtain the total expenses the optimization problem described in the next chapter has to be solved.

2.2. Optimization problem

Calculating the total expense of fertilizing is a stochastic optimisation problem. The problem is solved by running Monte Carlo simulations to generate the possible nutrient requirement scenarios and applying linear programming to obtain the most cost efficient fertilizer allocation for each scenario. Table 4 contains publicly available data on artificial fertilizers, namely the ratio of nutrient j in 1 kg of fertilizer f (denoted with RNF_f^j) and its price (with taxes). The products are indicated with the index $f \in \{AF1, AF2, \dots, AF15\}$. The LP used is described as follows.

Table 4. Publicly available data of artificial fertilizer products

Product	Ratio of nutrients in 1 kg of fertilizer (RNF)			Avg. Price [HUF/kg]
	N	P	K	
AF1	0.12	0.52	0.0	105.30
AF2	0.27	0.0	0.0	117.28
AF3	0.18	0.25	0.0	157.40
AF4	0.0	0.1	0.24	125.08
AF5	0.15	0.15	0.15	164.40
AF6	0.04	0.12	0.32	142.20
AF7	0.06	0.12	0.24	132.77
AF8	0.08	0.21	0.21	155.05
AF9	0.0	0.0	0.6	172.98
AF10	0.0	0.205	0.0	98.78
AF11	0.34	0.0	0.0	165.29
AF12	0.11	0.11	0.21	301.63
AF13	0.08	0.11	0.23	298.45
AF14	0.45	0.0	0.0	325.19
AF15	0.12	0.11	0.18	301.64

Sources: www.agro-store.hu, www.mutragya.hu, www.gazdabolt.hu, March 3, 2015.

2.2.1. Variables

$X_{i,f}$: Real-valued variables, representing the amount of artificial fertilizer *f* allocated to field *i* in kilograms (not to be confused with $X_{i,k}^{j}$, which are random variables in the simulation).

$Y_{i,f}$: The binary equivalent of $X_{i,f}$ (a flag representing whether any amount of fertilizer *f* is allocated to field *i* – also not to be confused with Y_i).

Z_i: The number of different types of artificial fertilizer allocated to field i. Z_i is calculated as

$$Z_i = \sum_{\forall f} Y_{i,f} \,. \tag{12}$$

2.2.2. Objective function

The objective is to minimize the total expense of fertilizing. The expense of fertilizing consists of two components: the cost of artificial fertilizer and the aggregated cost of its distribution. The aggregated cost of distributing artificial fertilizer in 2014 in Hungary is 0.2889 $\mathrm{Ft/m^2}$ (Gockler, 2014). It is assumed that only one kind of artificial fertilizer can be distributed simultaneously on each field – therefore the aggregated cost of distributing fertilizer on a field should be multiplied by the number of different fertilizers allocated to said field. The objective function can be written as

$$minimize \sum_{\forall i} \left(\sum_{\forall f} X_{i,f} \times Price_f + Z_i \times A_i \times 0.2889 \right). \tag{13}$$

2.2.3. Constraints

The objective is subject to only two kinds of constraints, namely to satisfy the different nutrient requirements of each field and non-negativity. The right hand side of the nutrient requirement constraints depend on whether crop residues are returned to the soil or not. Equation (13.a) shows the constraints given no residue is returned, while equation (13.b) shows the (corrected) constraints when crop residues are returned. Equation (14) is the non-negativity constraint.

$$\sum_{\forall f} X_{i,f} \times RNF_f^j \geq NR_i^j, \forall i, j. \tag{14.a}$$

$$\sum_{\forall f} X_{i,f} \times RNF_f^j \geq NR_i^j - R_i^j, \forall i,j. \quad (14.b)$$

$$X_{i,f}, Y_{i,f}, Z_i \geq 0, \forall i,f. \quad (15)$$

3. Simulation results

Reaching a convergent state is a key factor in case Monte Carlo simulations are involved. After 10,000 iterations the simulated results converge (Figures 1-4, convergent state represented by red dashed lines).

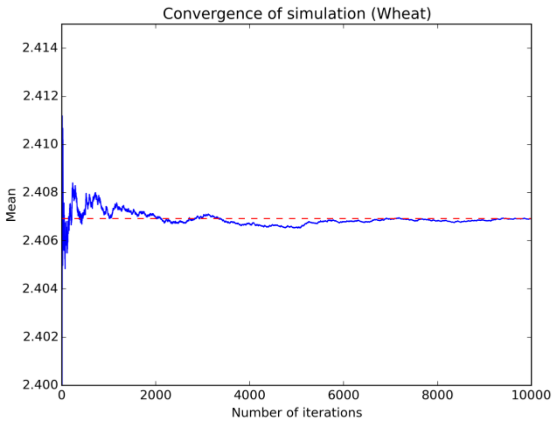

Figure 1. Convergence of wheat savings

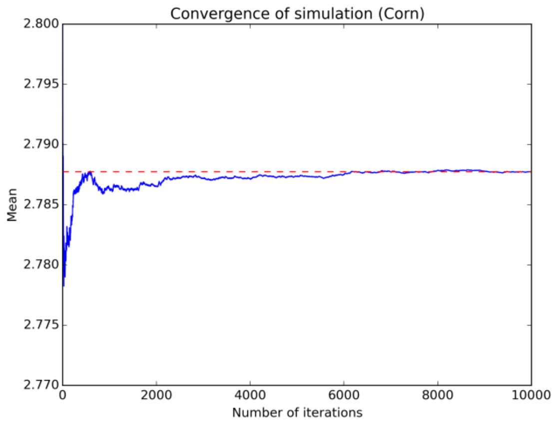

Figure 2. Convergence of corn savings

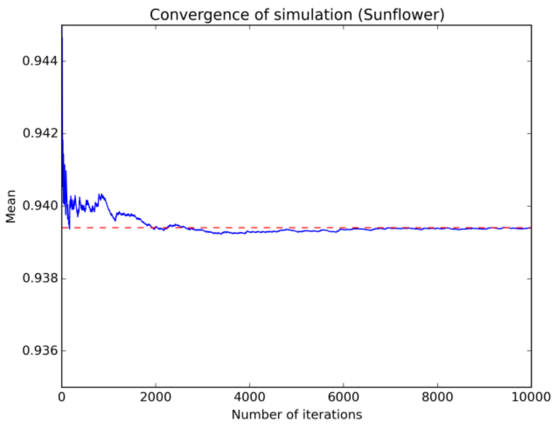

Figure 3. Convergence of sunflower savings

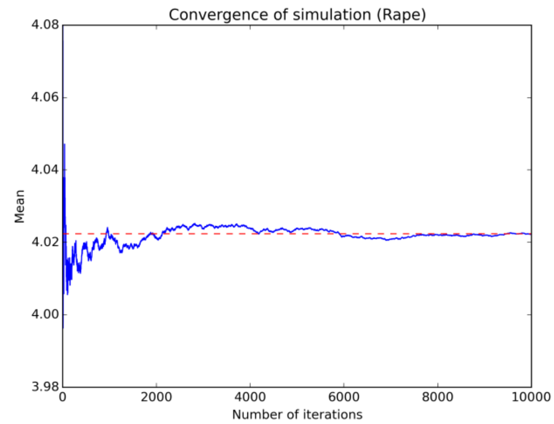

Figure 4. Convergence of rape savings

The expected value and standard deviation of savings are presented in Table 5. We can see that the standard deviations are very low, but considering that these values pertain only to a square meter the effects of uncertainty can vary in wide ranges given a high number of square meters involved.

Table 5. Expected value and standard deviation of savings

Residue	Expected value [Ft/m^2]	Standard deviation [Ft/m^2]
Wheat	2.4069174	0.0256387
Corn	2.7877342	0.0362423
Sunflower	0.9394069	0.0110463
Rape	4.0223666	0.1815932

To provide a better understanding of this uncertainty the probability distributions of savings are included as well (Figures 5-8, expected values represented by red lines).

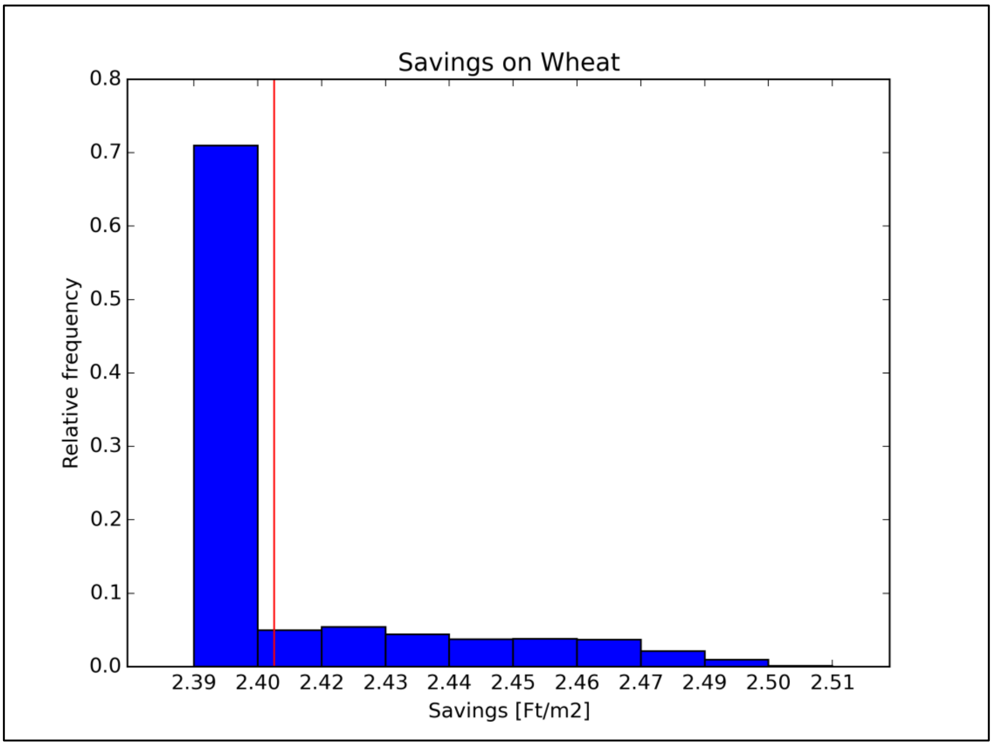

Figure 5. Relative frequencies of savings on wheat residue

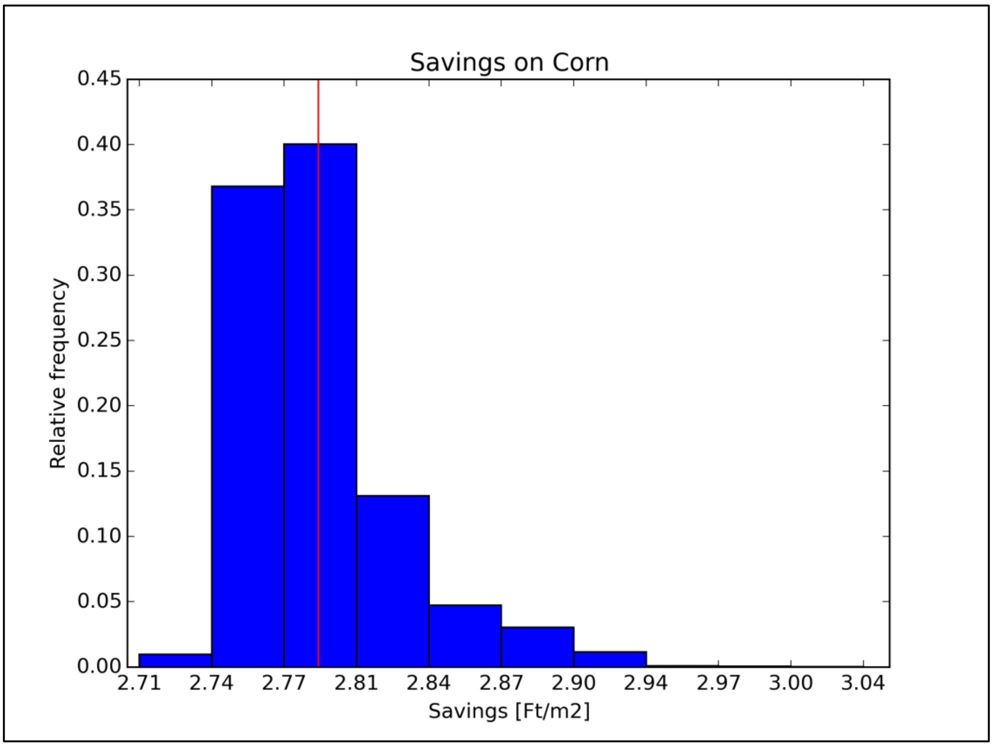

Figure 6. Relative frequencies of savings on corn residue

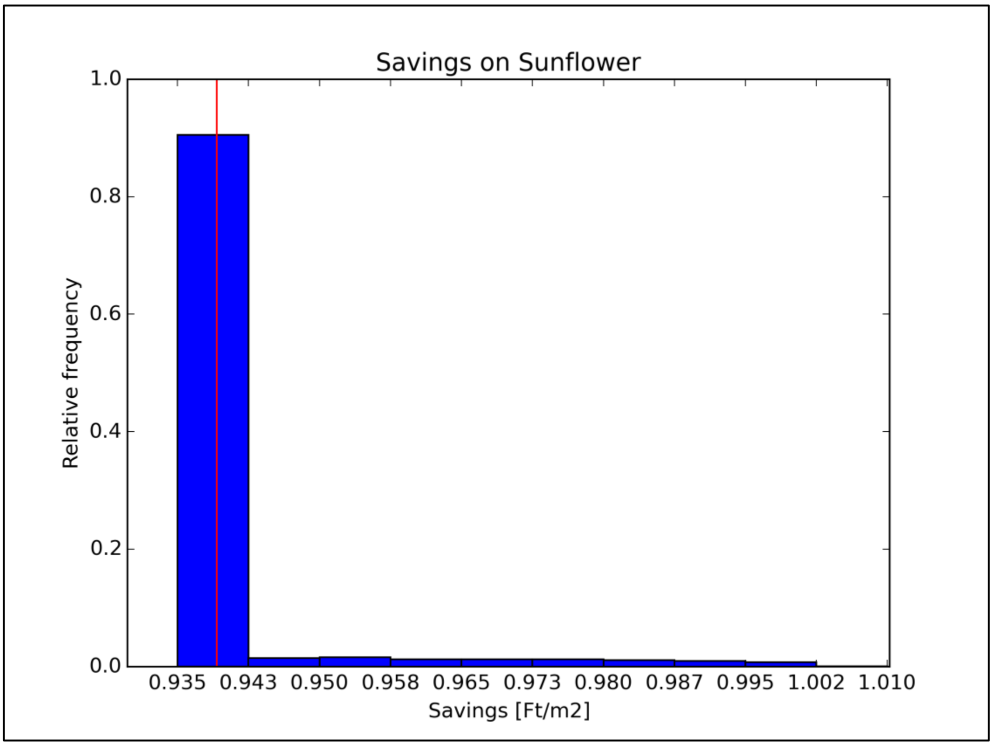

Figure 7. Relative frequencies of savings on sunflower residue

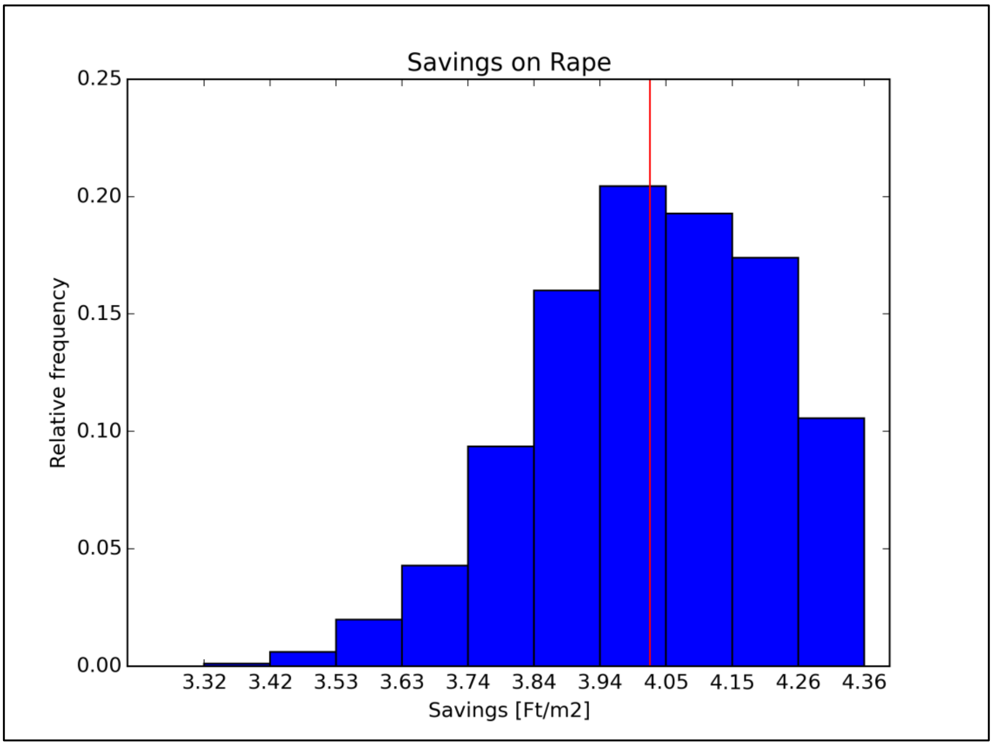

Figure 8. Relative frequencies of savings on rape residue

This uncertainty affects risks, thus has to be taken into consideration by financial decision making processes. Unfortunately no distributions fitted to the simulated data managed to achieve statistical significance based on the Kolmogorov-Smirnov, Anderson-Darling and χ^2 goodness-of-fit tests. Instead, the minimum and maximum values, the quartiles, and the 5th and 95th percentiles are provided (Table 6).

Table 6. Quantiles of the savings distributions

Residue	Min	$Q_{0.05}$	$Q_{0.25}$	$Q_{0.5}$	$Q_{0.75}$	$Q_{0.95}$	Max
Wheat	2.3921173	2.3923930	2.3924884	2.3925728	2.4128814	2.4682789	2.5100094
Corn	2.7065644	2.7461959	2.7621547	2.7798875	2.8008799	2.8698510	3.0358627
Sunflower	0.9352570	0.9359759	0.9360951	0.9361143	0.9361382	0.9670020	1.0097617
Rape	3.3205631	3.6987188	3.8999960	4.0329339	4.1709930	4.2785655	4.3597880

4. Conclusions

A mathematical model has been created that utilizes Monte Carlo simulation and linear programming to obtain the distribution of savings on residues of crops grown on arable land. The model is based on general concepts and it can be used not only to determine the value of crop residues but also to optimize artificial fertilizer allocation for any number of fields with differing planned crops and residues. Although the model assumes that crops fully exhaust the soil nutrients left in the field can be included into the calculations by adding them to R_i^j. Application of this model has different positive effects as well. The permanent dosage of high amounts of artificial fertilizer sours the soil – by optimizing the required amount this process can be slowed down. The distributions of savings can also be involved in further simulations to support decision makers. It is important to note that these distributions are based on nationwide data – in different regions they might look different. Researchers or other individuals are welcome to the Python implementation of the model upon personal request or by downloading it from the journal web site.

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Suitability of Current and Future Conditions to Apiculture in Egypt using Geographical Information System

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Apiculture, GIS, Egypt, honey bees.

ABSTRACT

Apiculture is currently considered as an important economic activity in Egypt. Most agricultural areas in Egypt are located close to Nile river as well as apicultural activities. Recently, various desert areas have been widely reclaimed and inhabited. In this study, the land suitability to apiculture in Egypt, either cultivated or desert areas, was investigated using geographical information system (GIS), under current and future conditions (2070). Two maps were extracted from the spatial analysis; one map for current conditions and the second one for future conditions. The study shows that most Egypt is suitable for apiculture but the more suitable areas are restricted to specific locations. In the future, land suitability was found to be impacted by future conditions, mainly thermal stress. Upper Egypt will be greatly impacted than the middle or north Egypt. Apiaries relocation is advisable especially at upper Egypt when necessary during 2070. It could be expected that apiculture could be practiced widely throughout Egypt currently and in the future as well, and in reclaimed lands. The spatial analysis was done using the major factors that could impact beekeeping; namely, maximum and minimum temperatures, precipitation, slope, land type, and distance from plants.

1. Introduction

Apiculture (beekeeping) has special importance to the agricultural sector in Egypt, and is increased actively every year. Most beekeepers depend mainly on the products of honey bee colonies as source of income. Because the development of honey bee colonies requires good vegetation, most apicultural activities is existed close to cultivated areas along the Nile River. It is known that the main food for honey bees is nectar (Nicolson 2008) and pollen (Huang 2012) collected from flowering plants. It could be said beekeeping in Egypt depends mainly on three flowering plants; citrus, clover and cotton (Hussein 2001). These plants are not available in all Egyptian governorates, hence, beekeepers usually transport their colonies from region to another to follow the flowering season. Apart from these main plants, honey bee colonies, in general, should be placed near to cultivated plants to get their feeding requirements. Placing honey bee colonies in barren lands could lead to the death of the colonies. Recently, desert reclamation is being done actively in Egypt (Abou-Shaara 2013a). It could be expected that apicultural activities can be greatly done in these regions. Hence, the first objective of this study is to identify the potential areas at which apiculture can be successfully practiced in Egypt including lands with desert nature.

To realize this objective, geographical information system (GIS) can be considered as a proper way. GIS was used previously to achieve somewhat similar objectives; e.g. rangeland suitability for beekeeping (Amiri & Shariff 2012), suitable wintering sites for honey bee colonies (Abou-Shaara 2013b), and to identify the suitable locations for using modified beehives in Saudi Arabia (Abou-Shaara et al. 2013a), and for other purposes related to honey bees (see, Myung-Hee et al. 2001; Coulson et al. 2005). GIS has a good ability to analyze different datasets and to present the results on maps with geographical nature, even if these datasets are related to honey bee morphology (Abou-Shaara 2013c). Honey bee colonies are impacted by many factors including; temperature, precipitation, slope, land cover and distance from plants (e.g. Amiri et al. 2011; Amiri & Shariff 2012;

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Abou-Shaara et al. 2013b). These factors have special importance to honey bees because they can greatly impact all the activities of honey bee colonies. For example, temperature is very important for brood rearing and development (Petz et al. 2004 & Tautz et al. 2003) and foraging activity (Blazyte-Cereskiene et al. 2010) while vegetation is very important as source of food to honey bee colonies even at desert areas (Zaitoun & Vorwohl 2003).

Nowadays, climate change is considered to be the main future challenge to apiculture (Yoruk & Sahinler 2013). Climate change can impact honey bee colonies directly (Le Conte & Navajas 2008), or indirectly by impacting flowering plants (Rader et al. 2013). Expecting the potential impacts of climate change on land suitability to apiculture is very important to help decision makers to take the right actions in the proper times. Therefore, the second objective of this study is to identify the potential areas at which apiculture can be successfully practiced in the future, and to compare it with the suitability map of current conditions. To achieve this objective, the available future temperatures and precipitation, beside slope, land cover and distance from plants were incorporated into the GIS spatial analysis to obtain the future suitability map. In light of this study proper recommendations for beekeepers are presented.

2. Methodology

2.1. Study location

The study was performed to cover all Egyptian governorates, representing a total area of about 1 million square kilometers. Egypt is located in northwest Africa between longitudes of 25° and 35°E, and latitudes of 22° and 32°N. Very few areas are with high altitude of more than 835 m above sea level while the most areas have altitude less than 218 m, (Figure 1).

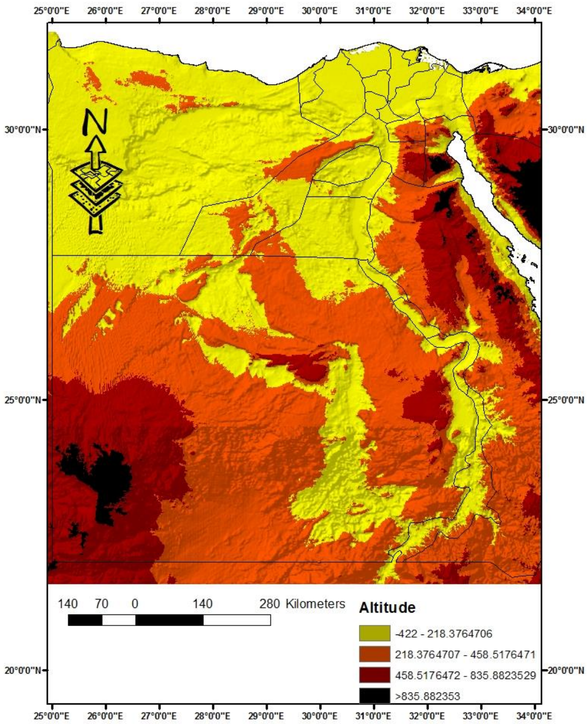


Figure 1. Map of Egypt shows the altitude.

2.2. Land suitability to apiculture

The land suitability to apiculture was identified using GIS spatial analysis. ArcGIS 10 was used to perform the analysis. Factors incorporated into the study were selected based on previous investigations of Amiri et al. (2011), Amiri and Shariff (2012), Abou-Shaara (2013b) and Abou-Shaara et al. (2013b). Apiculture is impacted mainly by some factors more than others (namely, maximum temperature, minimum temperature, land cover, distance from plants, precipitation during winter, and slope). Layers of the studied factors were obtained from DIVA-GIS.com for land cover and elevation, and from Worldclim.com for temperature and precipitation. Presented limits in Table 1 of studied factors were assigned according mainly to the work of Abou-Shaara (2013b) and Abou-Shaara, et al. (2013b). Land cover data as grid and with resolution of 30 seconds were used to create the land cover layer. All land cover types were considered as artificial lands and classified as unsuitable, except vegetation (cultivated area) which was classified as more suitable to apiculture. To extract distance from plants layer, the land cover layer was saved as raster layer, and then Euclidean distance from cultivated plants expressed as units was calculated using spatial analyst tools. Slope was calculated using elevation map with resolution of 30 seconds using surface tools from spatial analyst tools menu of the ArcGIS.

Layers of maximum and minimum temperatures, and precipitation were downloaded as ESRI grid (raster) format from Worldclim.com, and then these layers were classified as shown in Table1 and saved as raster layers. Investigated factors were classified into three categories; more suitable, suitable or unsuitable to apiculture. The more suitable regions have temperature from 10 to 37ºC throughout the year, winter precipitation less than 30, land with slope less than 7 degrees, and should be near to cultivated areas. These parameters were selected to ensure that honey bee colonies will not be under any environmental stress, and in accordance with previous studies. It has been found that very low temperature below 10ºC can hinder foraging activity (Joshi and Joshi, 2010) as well as very high temperature (Al-Qarni 2006 & Blazyte-Cereskiene et al. 2010). The high winter precipitation prevents worker foraging to gather food as reviewed by Abou-Shaara (2014). The uneven land or land with few plants is not suitable to establish apiaries in them (Abou-Shaara 2013b). The acceptable limits with few impacts on honey bees were considered as suitable while the completely unacceptable conditions were considered as unsuitable as shown in Table 1, including artificial lands, lands with very high slope or lands located far from plants, and regions with very high or very low temperatures. Because range of maximum and minimum temperatures differed from season to another, seasonal temperatures were incorporated into the spatial analysis individually. The maximum temperature during spring and fall as well as minimum temperature during summer were not included into the analysis because their ranges were found to be suitable to honey bees (from 10 to 37.9ºC), and it was not possible to classify their ranges into different suitability degrees.

Table 1. Limits and suitability degree for used temperatures, land cover, distance from plants, slope and precipitation in GIS spatial analysis.

Factors (range)	Limits	Suitability Degree
Winter temperature.	> 10	More Suitable
Minimum temp. (-3.7- 14.8°C)	< 10	Unsuitable
Maximum temp. (6.7 - 26.3°C)		
Spring temperature.	> 10	More Suitable
Minimum temp. (2.5 – 19.3°C)	< 10	Unsuitable
Summer temperature.	< 37	More Suitable
Maximum temp. (21.4 – 40.3°C)	> 37	Unsuitable
Fall temperature.	> 10	More Suitable
Minimum temp. (-4.8 - 26.9°C)	< 10	Unsuitable
	Cultivated lands	More Suitable
Land cover (types)	Artificial lands	Unsuitable
	0 – 0.3	More Suitable
Distance from plants (units)	0.3-0.6	Suitable
(0-3.26)	> 0.6	Unsuitable

Precipitation-winter. (0 - 44 mm)	< 30	More Suitable
	> 30	Suitable
Slope (degrees)	0 – 7	More Suitable
	7 -16	Suitable
	> 16	Unsuitable

To obtain the final suitability map, after classifying the prepared layers of studied factors into different classes, the layers were combined together using raster calculator tool. All the layers were combined at the same weight in accordance with Abou-Shaara et al. (2013b), because all the layers have the same importance in regard to identify suitable apiary locations. To validate the used model, random locations were selected from different governorates in Egypt and were compared by real images of Google Earth to ensure their suitable location to apiculture (e.g. close to cultivated areas).

2.3. Land suitability to apiculture in the future (2070)

Datasets of maximum and minimum temperatures, and winter precipitation during 2070 (representing means of 2061 to 2080) were obtained from global climate models of Beijing climate center_climate system model (BCC_CSM1.1), using representative concentration pathways 45 (rcp 45). These future conditions were incorporated into the spatial analysis as shown in Table 2, beside the previously mentioned factors (namely; slope, land cover type, and distance from plants, these layers were used typically as mentioned in Table1). Only minimum temperature during summer was considered as suitable to all regions with range from 13.1 to 29.5°C, thus it was not included into the analysis. Datasets were combined at the same weight to all factors to obtain the final suitability map. Suitability maps of current and future conditions were compared to identify potential future changes.

Table 2. Maximum and minimum temperatures, and precipitation during 2070, their limits and suitability degree used in the GIS analysis.

Factors (range)	Limits	Suitability Degree
Winter temperature. *Minimum temp.* (-15.7- 16.8°C) *Maximum temp.* (9.3 - 28.3°C)	> 10	More Suitable
	< 10	Unsuitable
Spring temperature. *Minimum temp.* (5.2 – 21.9°C)	> 10	More Suitable
	< 10	Unsuitable
Summer temperature. *Maximum temp.* (26.1 – 45°C)	< 37	More Suitable
	> 37	Unsuitable
Fall temperature. *Minimum temp.* (7.6 – 25.4°C)	> 10	More Suitable
	< 10	Unsuitable
Spring and Fall. *Maximum temp.* (19.2 – 39°C)	< 37	More Suitable
	> 37	Unsuitable
Precipitation-winter. (0 – 44.67 mm)	< 30	More Suitable
	> 30	Suitable

3. Results and Discussion

3.1. Land suitability to apiculture

As shown in Figure 2, the more suitable locations for apiaries are existed near to Nile River where the cultivated areas are existed. In Egypt, agriculture depends on Nile River as the main source for irrigation, and relatively few cultivated areas are existed in deserts as shown in Figure 3. The map (Figure 2) shows that many locations were classified as suitable to apiculture in desert areas. These locations were likely classified as suitable and not as more suitable due to the absence of cultivated areas (vegetation). The desert regions were, in general, classified as unsuitable, mostly because high slope, and the absence of cultivated areas beside the unsuitable climatic conditions according to the used factors in the spatial analysis.

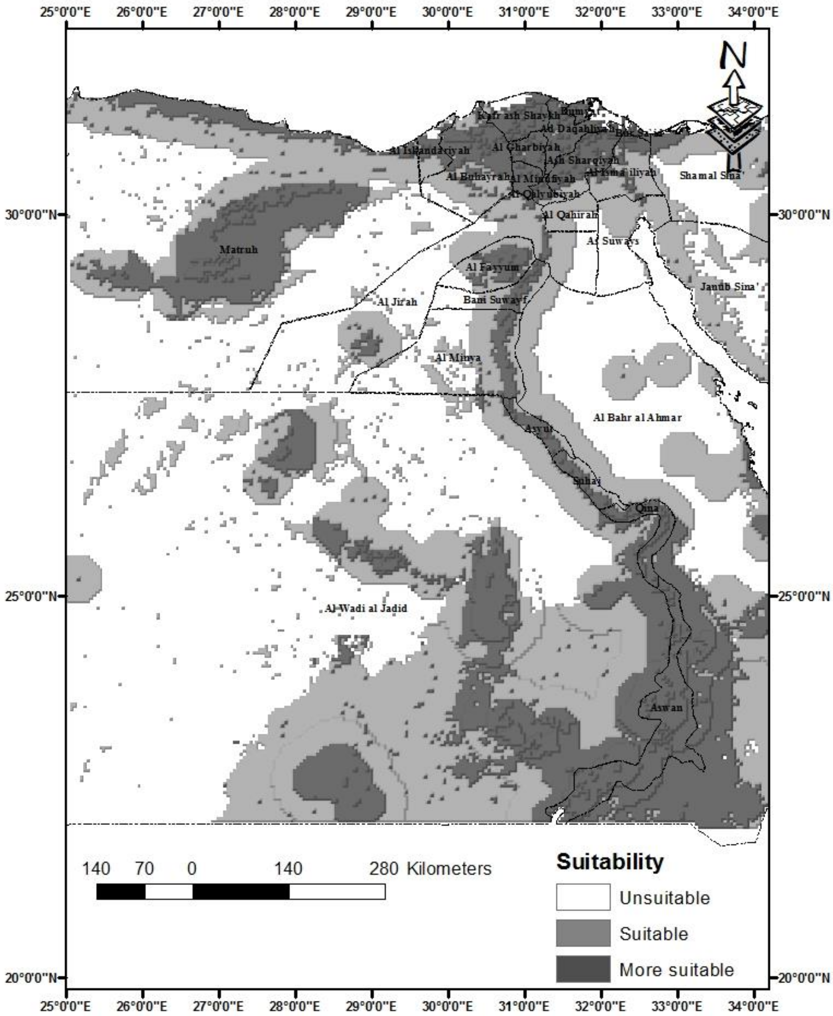
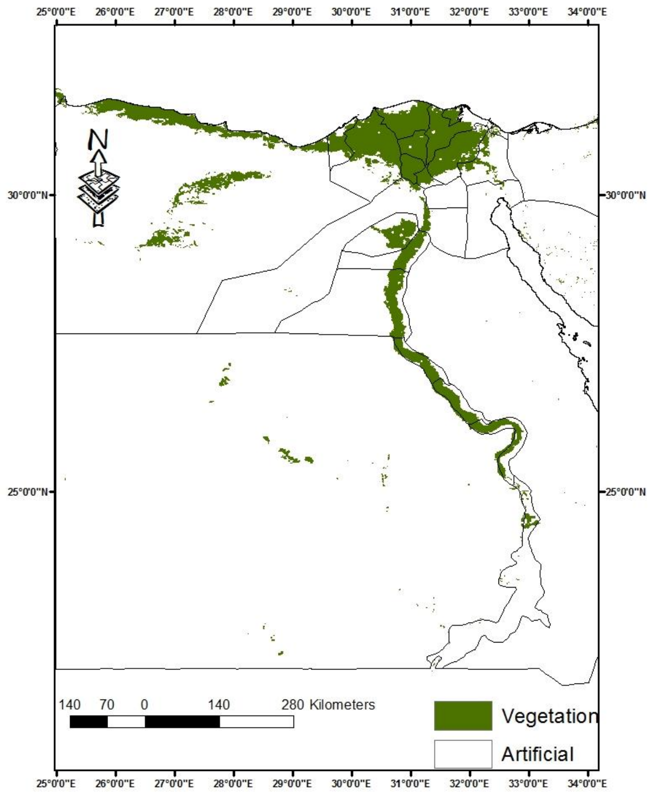


Figure 2. Suitability map for apiary locations under current conditions.

Figure 3. Approximate vegetation map to Egypt, all other things except plants in this map were classified as artificial.



Some random locations were selected within the more suitable regions for apiculture as presented in Table 3. The locations were selected randomly mainly from regions with desert nature at three different governorates; Matruh, Shamal Sina (North Sina), and El-Bahar El-Ahmar (Red Sea).

Table 3. Longitude (Long.) and Latitude (Lat.) of selected locations within more suitable areas at Matruh, Shamal Sina, and El-Bahar El-Ahmar governorates.

Point	Location (coordinates D.D.)		
	Matruh	Shamal Sina	El-Bahar El-Ahmar
A	Long. 26.418 Lat. 31.404	Long. 33.806 Lat. 31.116	Long. 33.083 Lat. 25.157
B	Long. 27.66 Lat. 29.856	Long. 34.157 Lat. 30.62	Long. 33.899 Lat. 26.569
C	Long. 25.878 Lat. 29.184	Long. 34.318 Lat. 30.021	Long. 34.337 Lat. 24.537

The selected locations within the more suitable areas at El-Bahar El-Ahmar governorate (Red Sea governorate) shows that the locations are typically existed in desert lands but relatively near to cultivated areas (Figure 4). These locations based on the used model have good climatic conditions, and even lands. According to the suitability map, the surrounded areas to these locations are either more suitable or suitable to beekeeping, while lands with harsh nature were classified as unsuitable. It could be said that the Google Earth map is in line with the suitability map obtained from the spatial analysis, suggesting that the used model is suitable to identify potential apiary locations.

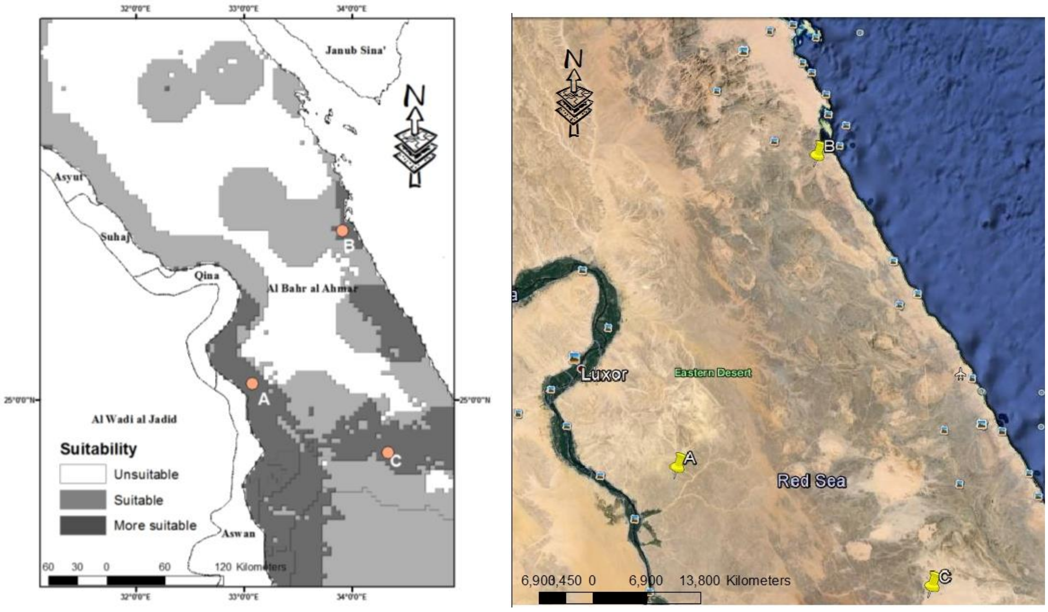


Figure 4. Three randomly sleceted locations; A, B, and C within the more suitable areas at El-Bahar El-Ahmar governorate (Red Sea governorate). Left: Suitability map obtained from the GIS, and Right: Real map from Google Earth shows the selected locations marked with yellow land marks.

The selected locations at Matruh governorate within the more suitable areas (Figure 5) are located close to cultivated areas except location (A) which was located approximately in desert area with very few plants. As said with the previous locations at Red Sea governorate, these locations have the more suitable conditions to beekeeping. The close view to location (C) presented in Figure 6, confirms that this location in very close to Siwa oasis (an oasis with good climate and vegetation). It could be said that although the desert nature of most areas, still beekeeping is suitable to be practiced in them. Accordingly, Abou-Shaara (2013b) found most areas at El-Behera governorate were suitable to keep honey bee colonies during winter including desert areas.

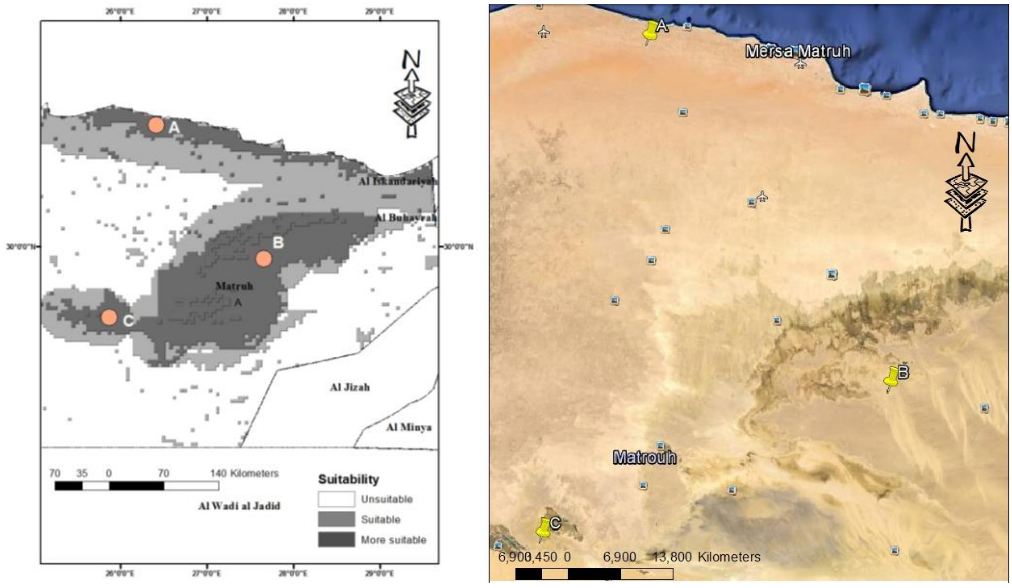


Figure 5. Randomly selected locations; A, B, and C within more suitable areas at Matruh governorate. Left: Selected locations on the suitability map, and Right: selected locations as yellow land marks on Google Earth map.

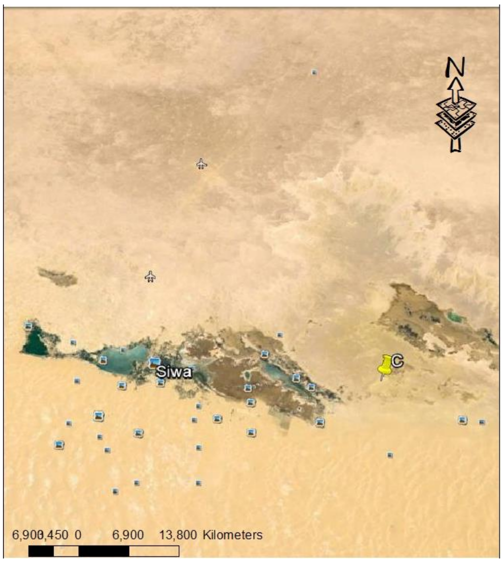


Figure 6. Close view to location C and Siwa oasis.

Similarly to the previous two governorates, the randomly selected locations are existed in areas which can be considered as more suitable to apiculture (Figure 7). As shown in Figure 8, location A is existed in cultivated areas and near to Arish city that supports the validation of the used model. It is clear that the more suitable areas are very small likely due to the desert nature of this governorate. The areas classified as suitable are relatively large due to small cultivated areas, and the general harsh conditions of this governorate. Areas classified as unsuitable could be explained mainly due to the unsuitable land slope and the absence of cultivated plants.

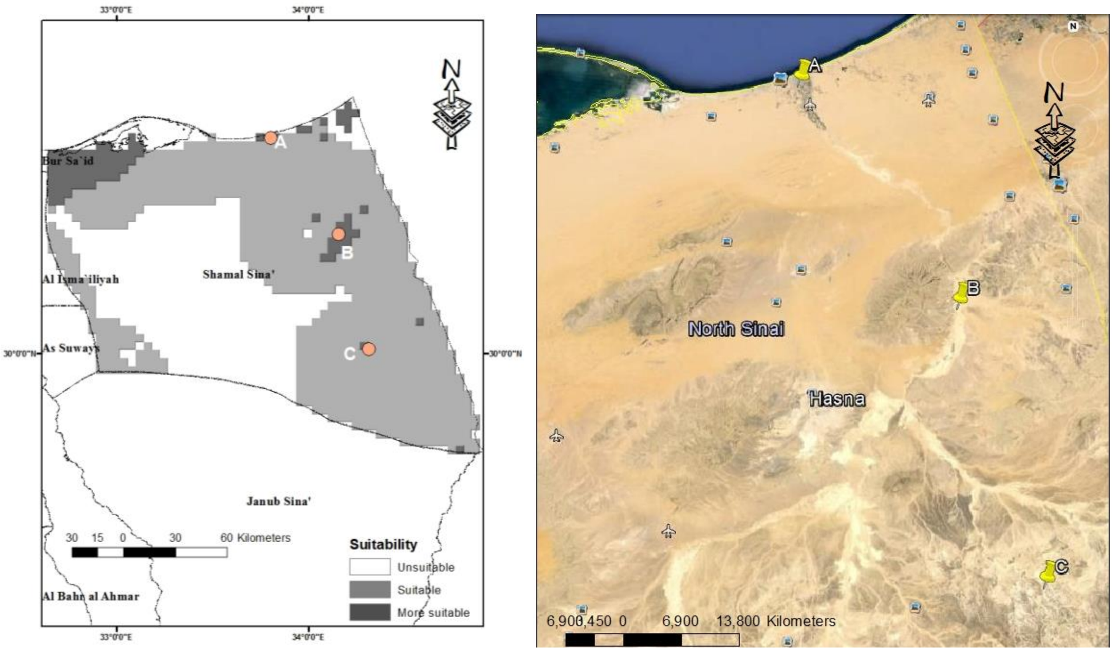


Figure 7. Randomly selected locations; A, B, and C within the more suitable areas at North Sina governorate. Left: suitability map with selected locations, Right: Selected locations marked with yellow land marks on Google Earth map.

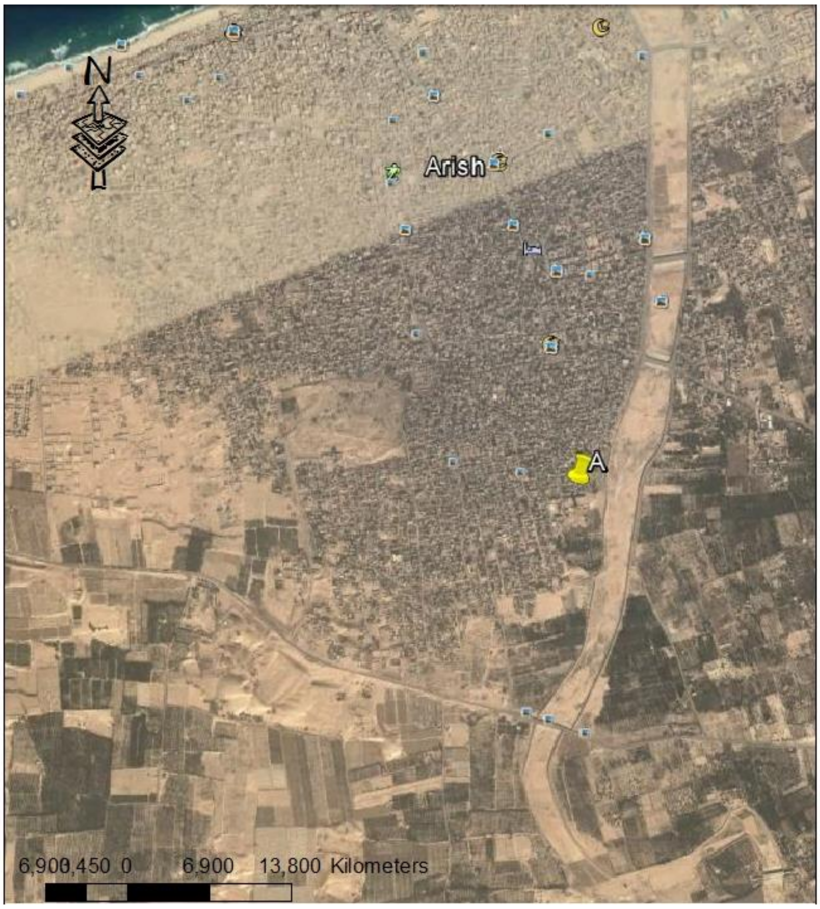


Figure 8. Location (A) is close to cultivated areas and Arish city.

3.2. Land suitability to apiculture in the future (2070)

Figure 9. shows the variations between current and future suitability maps. It is clear that most Upper Egypt will be less suitable to beekeeping than nowadays, and some areas will be unsuitable to apiculture. That could be explained by climate change, and mainly heat stress on honey bee colonies at these regions. Similarly, suitability of regions around the Nile River to apiculture will be impacted by future conditions, and will be with less suitable to apiculture. The impact on north Egypt will not be huge, however some regions currently classified as unsuitable will be suitable to apiculture in the future. Additionally, it has been found that land reclamation at North West Egypt is done actively (Abou-Shaara 2013a), that supports the expectation that apiculture will be widely done at north Egypt in the future than currently. It could also be said that climatic conditions in north Egypt will be somewhat in favor to apiculture rather than current conditions, including desert areas. It is expected that protecting honey bee colonies from thermal stress in the future will be necessary. Using modified beehives to keep honey bee colonies in the future could be considered to be a correct way, as done previously by Abou-Shaara et al. (2013c) in Saudi Arabia, they used different modified beehives to protect honey bee colonies during summer.

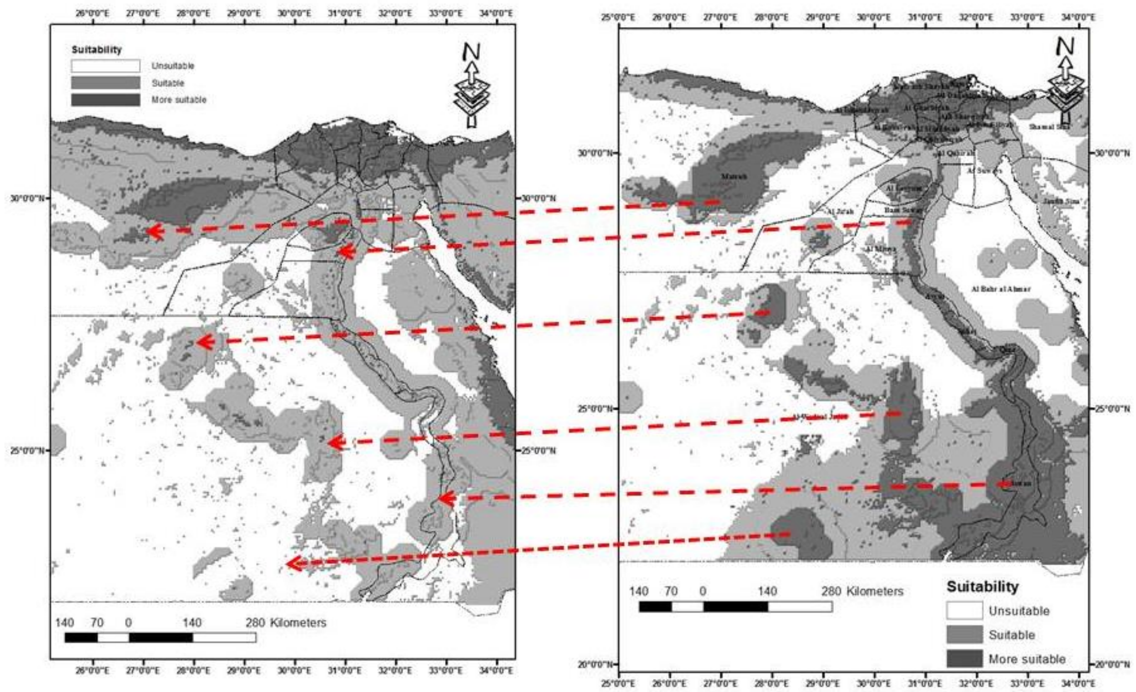


Figure 9. Future suitability map (left) and current suitability map (right). Areas with clear variations were denoted by red arrows.

4. Conclusion

According to the suitability analysis to apiculture, Egypt map was classified into three categories; unsuitable, suitable or more suitable. Most areas were classified as suitable or more suitable while the very harsh ones were classified as unsuitable. The results reflect the high potential of using land at different governorates to apiculture. It could be expected that land suitability to apiculture will be greatly impacted by future conditions especially at upper Egypt, and more areas in the north will be suitable to apicuture. Beekeepers in the near future may had to change their current apiary locations. Searching for suitable procedures to protect honey bee colonies from thermal stress in the future are strongly recommended.

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Land Suitability Assessment For Effective Crop Production, a Case Study of Taita Hills, Kenya

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DEM, RUSSLE, NDVI, Land Suitability, Soil Erodability

A B S T R A C T

Agriculture is the backbone of Kenya's economy. Agriculture in Kenya is characterized by low productivity due to low external inputs, lack of good farming practices, soil erosion, and other losses. In most farming regions of the country, agriculture depends entirely on rainfall which sometimes is scarce. The problem of selecting the correct land for the cultivation of certain crops is a long-standing and mainly empirical issue. The objective of this study is to extrapolate and generate a crop suitability map showing areas suitable for agricultural activities in Taita Hills in Kenya. It utilizes the information on environmental condition, altitude, rainfall and other relevant parameters of the case study where the variability of rainfall and recurrent droughts have a great impact on the lives of people whose livelihood is mainly dependent on subsistence agriculture. The methods used include development of elevation models, watershed mapping, climate variability mapping, soil erosion mapping that incorporates the revised universal soil loss empirical (RUSSLE) model and multi-criteria evaluation analysis. The analysis was done using the sum weighted overlay analysis of soil erodibility, slopes, vegetation index and rainfall availability in the modeling. Four categories were achieved and mapped out: most suitable, more suitable, less suitable and least suitable. The research implies that there can be both suitable areas and unsuitable areas for crops in Taita Hills. The study helps farmers to be aware of the environmental conditions of their agricultural land and the impacts that may arise due to varying climate conditions on their cropping patterns.

1. Introduction

Many researchers have tried to prepare a standard framework for suitable and optimum agriculture land use. FAO (1996) classifies agricultural potential based on soil and environmental characteristics into five classes including highly suitable, moderately suitable, marginally suitable, currently not suitable and permanently not suitable. There have been instances of frequent crop failures of late. The occurrence of hydro-climatic events such as droughts and floods increase in many parts of the country (e.g. Taita Taveta County), causing severe socio-economic impacts that include food insecurity, famine, deaths, epidemic diseases, pests and economic losses among others. These impacts seem to spread over large areas and differ in severity, magnitude and duration. The problem has caused public outcry for good information on agricultural farming practices for planning and management purposes. A suitability assessment is an important phenomena for a region or a country to engage in more

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rational planning and optimizing resource use for the present and in the future (Zomer et al., 2008, Malczewski et al., 2001 & Bojórquez et al., 2001).

Land suitability refers to the ability of a portion of land to tolerate the production of crops in a sustainable way. Such kind of analysis allows identification of the main limiting factors for the agricultural production and enables decision makers (Joerin et al, 2001 & Miguel et al., 1998) to develop crop managements that is capable of increasing the land productivity (Rabia 2012; Pererira & Duckstein, 1993; Marull et al., 2007).

2. Study Area

Taita Hills (03 25' S and 38 20' E) are the northernmost part of the Eastern Arc Mountains of Kenya and Tanzania covering an area of approximately 850 km2 (Figure 1). They are characterized as an island of fertile mountain area surrounded by the dry bush lands of Tsavo East and West National parks situated about 150 km from the coast of Kenya immediately south of the Mombasa – Nairobi (Soni, 2005). The hills make up the administrative divisions of Wundanyi and Mwatate in Taita-Taveta County. These ancient Precambrian hills sit an altitude ranging from 1200 – 2200 meters a.s.l rising from the Tsavo Plains (Pellikka et al., 2012).

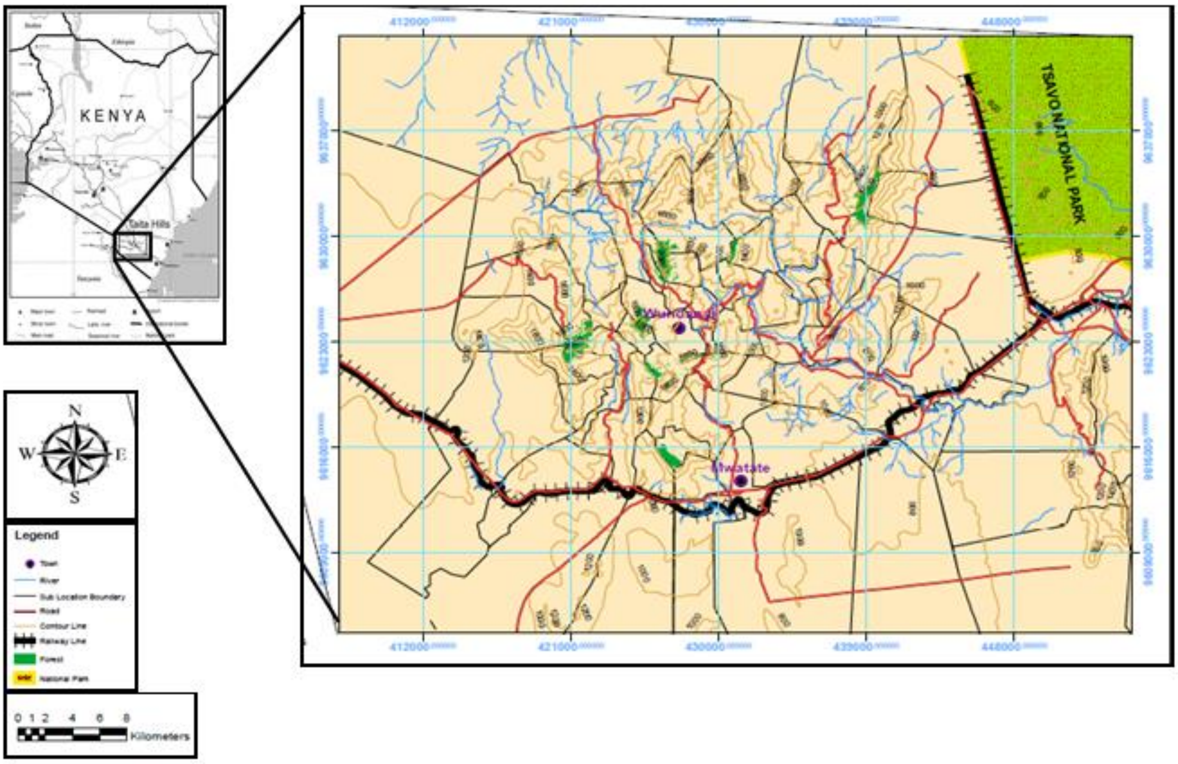

Figure 1. Taita Hills Map

The main basis of the living in the highlands is intensive agriculture, which is the main source of livelihood for 78% of people in the district (Pellikka et al., 2012). The population has doubled within 30 years and the highest growth rates are reported among the younger age groups. The pressure on land also results in increased human-wildlife conflicts as well as land use disputes between farmers and managers of sisal plantations and national parks (Pellikka et al., 2012).

2.1. Demographics, Agriculture, Terrain and Climate of Taita Hills

The population of the whole Taita-Taveta county has grown from 90,146 persons in 1962 to approximately 280,000 in the year 2009 (KNBS, 2010). According to Clark (2010), population growth has been a central driving factor behind rising environmental pressure. The population distribution is varied with most people living in the high potential areas of the foot slopes of the hills and in urban centres (NEMA, 2009). The upward trend of population growth in the Taita hills started in the mid

1920's (Soni, 2005). By the end of 1960's population had almost tripled from the 40,000 in the early 1930's to about 111,000 in 1969 (Figures cited by Mkangi (1978)).

The indigenous cloud forests have suffered substantial loss and degradation for several centuries as abundant rainfall and rich soils have created good conditions for agriculture. Between 1955 and 2004, approximately half of the cloud forests in the hills have been cleared for agricultural lands (Pellikka et al., 2009). Population growth and increasing areas under cultivation for subsistence farming have caused a serious scarcity of available land in the hills and contributed to the clearance of new agricultural land in the lowlands (Clark 2010). Currently, it is estimated that only 1% of the original forested area remains preserved (Pellikka et al., 2009).

The agriculture in the hills is characterized by intensive small-scale subsistence farming. In the lower highland zone and in upper midland zone, the typical crops are maize, beans, peas, potatoes, cabbages, tomatoes, cassava and banana. In the slopes and lower parts of the hills with average annual rainfall between 600 and 900 mm, early maturing maize, sorghum and millet species are cultivated. In the lower midland zones with average rainfall between 500 and 700 mm, dryland maize varieties and onions are cultivated, among others. Located in the inter-tropical convergence zone, the area has a bimodal rainfall pattern, the long rains occurring in March–May and short rains in November-December. The region has two crop growing seasons, which coincide with the long and the short rains (Jaetzold & Schmidt, 1983). Together, both crop growing seasons account for 150–170 days. The land is prepared during the dry season, and the crops are seeded prior to the short rains and long rains. Harvesting takes place after the end of the rainy seasons.

Taita Hills is facing a population growth and intensification of agriculture, which is the major economic activity for the Taita community (Boitt et al., 2014) with Horticulture dominating the agriculture based economic activity in the area (NEMA, 2009). Despite the large importance of agricultural activities for the economy and food security in the Taita Hills, the expansion of croplands imposes serious threats for the environment. Understanding the driving forces, tendencies and patterns of land changes is an essential step for elaborating policies that can harmonize land use allocation and natural resources conservation. Land use and soil erosion are closely linked with each other, with local climate and with the society. The expansion of agricultural areas in the Taita Hills and changes in precipitation patterns associated with climate change are imminent threats for soil conservation (Maeda et al 2010).

The crops grown in Taita Hills follow the altitudinal pattern of the area which in turn influences the Agro-ecological zones present. In the lower highland zone and in upper midland zone, the typical crops are maize, beans, peas, potatoes, cabbages, tomatoes, cassava and banana (Jaetzold & Schmidt, 1983). In the slopes and lower parts of the hills with average annual rainfall between 600 and 900 mm, early maturing maize, sorghum and millet species are cultivated. In the lower midland zones with average rainfall between 500 and 700 mm, dryland maize varieties and onions are cultivated, among others (Maeda, 2011). Maize and beans are the most important food crops and are mainly grown for subsistence. Other pulses are also grown and are mainly intercropped with maize. Planting of sorghum and millet in the hills is however rare, because their acceptance as food crops is low due to their unpopularity as food (NEMA, 2009). Arrowroot and cassava are very important food crops and an alternative when the maize crop fails. Sweet and Irish potatoes are also grown and consumed locally. The main livestock products are meat, milk, and hides (NEMA, 2009). Dairy production is more common in the upper zone of the Taita hills where the climatic condition and small land holdings are favorable for zero-grazing. The types of dairy cattle found in those areas are Friesian, Ayrshire, Guernsey and Jersey as well as crossbreeds. However, Taita Hills lack beef production because of small farm sizes (NEMA, 2009).

The Taita Hills complex rises above the erosional plains of the lowlands with small inselbergs. Its terrain pattern is largely contributed with geological processes whereby it is constituted by three major blocks namely the Sagalla, Taita and Kasigau (NEMA, 2009). The Taita Hills are block-faulted basement (crystalline) rocks in the Mozambique belt composed of Precambrian paragneisses from metamorphosed pelitic arenaceous and calcareous sediments from about 290 to 180 million years ago (NEMA, 2009). The surrounding plains lay at 500 - 600 m above sea level, while the highest peak of

Taita Hills, Vuria, reaches up to 2208 m (Pellikka et al., 2012). Generally, the terrain pattern of Taita Hills varies from 600 m to about 2200 m.a.s.l (Boitt et al., 2014).

The Taita Hills are strongly influenced by the Indian Ocean, forming a barrier to moisture-laden winds (Salminen, 2004). As a result, the area has two rainy seasons, one occurring during March-May and a shorter one during November-December. The mean annual rainfall ranges from 1332 to 1910 mm, with the southern and eastern slopes receiving more rainfall than western and northern slopes (Omoro et al., 2013) In addition, some parts of the Taita Hills receive cloud precipitation (Jaetzold & Schmidt, 1983). The amount of additional rainfall due to cloud precipitation (sometimes referred to as occult or horizontal precipitation) is unknown and difficult to quantify. Stadmüller (1987) reported relative values for cloud forest in the humid tropics ranging from 7 to 159% of annual rainfall while Bruijnzeel et al. (2010) reports that through fall exceeds annual rainfall in upper montane cloud forests by about 20% on average.

Recent past research by the National Environment Management Authority (NEMA) in the Taita-Taveta County Environment Action Plan for the period of 2009 – 2013, reveals that Taita Hills receive the highest amount of rainfall compared to other parts of the county. The high potential areas in the Taita Hills receive more than 900 mm of rainfall per annum (e.g. Wundanyi 1300 mm and Wesu 1400 mm) with temperatures average of 15 – 200C. The medium potential areas receive 700 to 900 mm, with higher temperatures, and evaporation (NEMA, 2009).

With increased regional slope, erosion systems have developed and have rendered the land unusable for agriculture and construction purposes. In areas more suitable for agriculture, uncontrolled deforestation, poor vegetation cover and overgrazing has led to removal of topsoil, leading to intense red patches and silting of local water supplies. The main causal factors are uncontrolled deforestation, overgrazing, surface compaction and poor land management. The impacts are severe; the loss of top soil leading to silting of reservoirs and rivers, a chronic reduction of soil fertility near the gully system, and the actual loss of productive land. (Sirviö et al., 2004 & Pellikka et al., 2012).

3. Methodology

The research was based in Taita Hills where the land is characterized with hilly topography. It is this nature of topography it possesses that almost all physiographic characteristics and consequently human activities are linked to. For this reason, the research considered a 3D data that formed the basis of all analysis and therefore a Digital Elevation Model (DEM) of Taita Hills was used. Apart from the DEM, the study utilized other data files amongst is soils data file which was in vector format and with associated attributes – soil drainage and pH. The analysis carried out necessitated consideration of the amount and nature of precipitation associated with the area of study a fact that led to incorporate Mean Annual Rainfall data which was in raster format. This was followed by using Mean Annual Temperature (raster format) data forming part of the data list. Since the research results are for the benefit of the human population including farmers, county government of Taita-Taveta, and stakeholders, the study considered having data on administrative spatial settlement units and therefore Sub-locations (in vector format).

With crop suitability mapping being the main focus of the research, all local factors positively and negatively affecting crop farming in Taita Hills were explored. It was concluded that crop farming in this area is not only affected by amount and distribution of rainfall, temperatures, altitude, and soils properties but also soil erosion. The analysis was consequently procedurally broken down into seven (7) phases:

i) Three dimensional mapping

Land suitable for crop farming in Taita Hills is to a large extent affected by the topography. The study therefore considered running 3-D analyses that have direct impact on the crop farming suitability situation. Since soil erosion has been spotted to be significantly affecting crop farming in Taita Hills, slope was treated as one of the determinant of soil erosion. The *slopes* in Taita Hills were then generated and mapped. *Contours* were then generated using the DEM. Water and eroded materials flowing from higher elevations follow certain pattern depending on the nature of the land which the study wanted to find out and therefore all **watersheds** were analytically delineated still using the DEM with the aid of Global Mapper Software.

ii) Mean annual rainfall mapping

The mean annual rainfall spatial distribution from the original data was mapped. Areas that receive the highest (high elevations and windward side) and lowest rainfall (low elevations and lee-ward side) were consequently identified.

iii) Soil mapping

Soil erosion levels are partially a product of soil variables. The variables combined for this mapping is the soil drainage, texture and organic contents. The study therefore used the soils data to map the drainage properties of soils in Taita Hills revealing the spatial distribution of this soil property.

iv) Mean annual temperature mapping

The mean annual temperature data was used in generating a map showing the spatial variations in temperatures within the area of study. This was used to infer the levels of evapo-transpirations.

v) Soil erosion mapping

Soil erosion was treated as one of the major determinants of crop farming in Taita Hills with areas associated with high soil erosion realizing low crop yields as opposed to areas with low or no soil erosion. GIS was used to model soil erosion by use of USLE/RUSLE (Wischmier & Smith, 1978; Renard et al, 1997) soil loss empirical model.

The spatial differences in the levels of soil erosion in Taita Hills by using mean annual rainfall to compute the rainfall intensities with intensity (Knijft et al, 1999) and a thresholds of 40mm and above was deemed erosive in the computation, soil erodibility (Harison et al, 2012); a combine of soil texture, available water content and gravel, study area population (KNBS 2010). The slope generated from DEM as detailed in (Morgan R.P.C, 1978 & Mitasova et al., 1996) as the determinants used in the modeling. The slope factor was a combine of slope length and steepness; LS factor, (Mitasova et al., 1996) and the vegetation index derived from the NDVI and the land use for the study area.

This task was accomplished by running sum weighted overlay of these determinants which were priori made raster data formats. In nature, rainfall, slopes and soil erodibility contributed varying magnitudes towards soil erosion phenomenon, a fact that was considered in this analysis. This phase of analysis was therefore done with two different ratios of weights in the sum weighted overlay analysis. The analysis was first done with ratio 3:2:1 of soil erodibility, slopes, vegetation index, and rainfall erosivity and population index carried equal weights in the modeling. After logical considerations of the situation in Taita Hills, the variable were validated with site visits to the specific locations of erosion and was found to be corresponding with the results obtained.

vi) Soil pH mapping

The relationship of soils pH and the levels of yields associated with them were studied and the same was linked to the situation in Taita Hills. Consequently, all soils with soil pH zero (0) were categorized as lowest crop yields soils, those with soil pH of ranges 5.1-5.3 & 8.3 were categorized as low crop yields soils, and soils with pH ranges of 5.7-6.4 & 7.9-8.0 were taken as soils which give high crop yields. This analysis was then mapped to bring out the spatial aspect.

vii) Crop land suitability mapping

This is the final phase of this analysis which the whole study was aimed at. Crop farming in Taita Hills was thought to be affected by soil erosion, soil pH, rainfall and temperature. The mapping categorized Taita Hills in four (4) crop suitability conditional zones terming them as *most suitable*, *more suitable*, *less suitable* and *least suitable*. All these aspects were analysed and mapped in the prior phases; they were therefore used to run a sum weighted overlay with the aid of Arc GIS. The categorization was thought in a way that all regions with lowest temperatures but high rainfall and least soil erosion as well as soil pH ranges that realize high crop yields to be the most suitable for crop farming. Whereas, regions which record low temperatures, above average rainfall, low soil erosion, and soil pH ranges which realize high crop yields to be more suitable for crop farming.

Less suitable regions for crop farming are thought to be areas with high temperatures and average rainfall but with high soil erosion and soil pH range which realizes low crop yields. Least suitable regions in Taita Hills for crop farming are taken to be those which record highest temperatures and low rainfall but with highest soil erosion and soil pH which realizes lowest crop yields (Table 1).

Table 1. Multi-criteria Analysis Parameters.

<table>
<tr><th>Mean Annual Temperature Level</th><th>Mean Annual Rainfall Level</th><th>Soil Erosion Levels</th><th colspan="2">Soil pH (Crop yields)</th></tr>
<tr><td>Lowest</td><td>Low</td><td>Least</td><td colspan="2">Lowest</td></tr>
<tr><td>Low</td><td>Average</td><td>Low</td><td colspan="2">Low</td></tr>
<tr><td>High</td><td>Above Average</td><td>High</td><td>High</td><td>High</td></tr>
<tr><td>Highest</td><td>High</td><td>Highest</td><td colspan="2">Highest</td></tr>
</table>

4. Results and Discussions

The results obtained from this research study were presented in form of maps. The use of fuzzy logic and of fuzzy sets theory applied as a means to arrive at a decision in this context. The fuzzy logic was used where the input variables were subjected to the modelling in ArcGIS. Fuzzy logics are the process of formulating the mapping from inputs to an output using fuzzy logic methods. The fuzzy logic mapping provides a basis for decision making, and logical arrangements of variables. The process of fuzzy logic inference involves Membership functions, Logical Operations, and If-Then Rules (Jiang & Eastman, 2000; Riad et al., 2011). The product outcome was reclassified into four main classes; less suitable, least suitable, more suitable and most suitable.

The results that were obtained from this research study were presented in form of maps that showed the scenarios in Taita Hills (Figure 2).

The mapping concept for this suitability analysis using GIS is very important to farmers in the current situation of global climate variations. Coupled with the Agro-ecological zones and having shown that in this research study, there shall be zone shifting in the coming years, precisely 2050, then farmers need to be aware of this situation so that they get prepared in time (Boitt et al., 2014). This study employs climate analysis and geophysical parameters in which the assumption is that the geophysical parameters won't affect or won't contribute so much to change however with the issue to do with soil erosion, due to huge amount of rains, the soil types and drainage pattern of Taita Hills can be of importance or consideration.

Soil erosion in Taita Hills is caused mainly by the intensive agriculture, cutting down of tress and even overgrazing. Huge amount of indigenous tropical cloud forest has been lost to agriculture between 1955 and 2004 although a balance was created by large-scale planting of exotic pines, eucalyptus, grevillea, black wattle and cypress on barren land during the same period which has not contributed much to the productivity of water catment or more agricultural yield. The investiment in this tree planting has not so far improved erosion downstream as the surfaces are still bare not fully covered by underneath vegetation that can reduce the rate of surface run-off. Indigenous forest loss may adversely affect ecosystem services in Taita Hills (Pellikka et al., 2009). From site visits and field measurements, the impacts of climate change to agricultural land in the region will be severe in the future if nothing is done to reduce such effects.

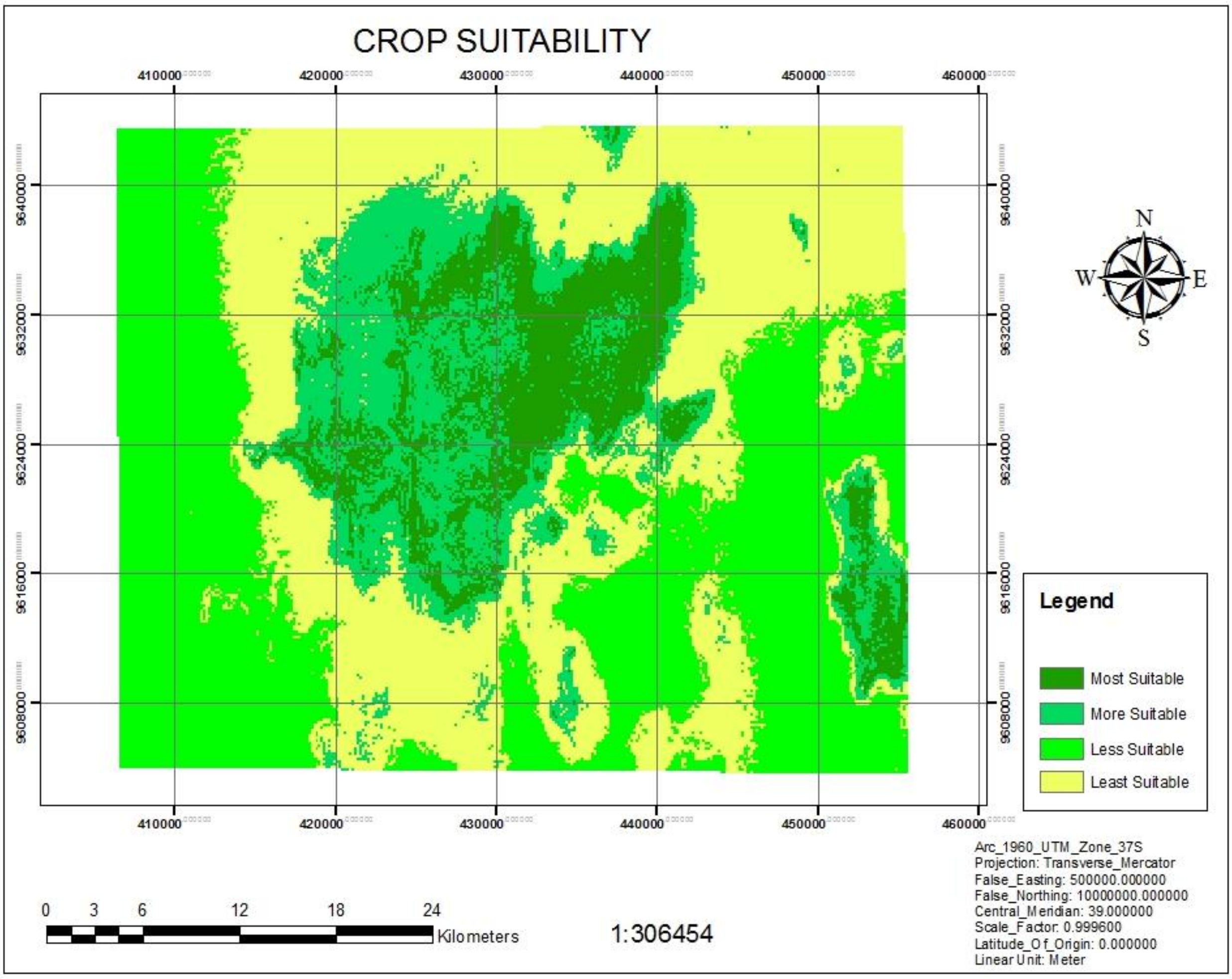

Figure 2. Crop-Land Suitability map for Taita Hills.

The implication of this study is a picture of what farmers need to know in regard to the best areas to grow their crops. In the areas which are most suitable for agriculture, farmers may not be forced to put so many efforts in order to realize a good harvest. In areas which are least suitable, it would be of importance for farmers either to put more fertilizers, do irrigation or in the event that it doesn't go on as they expect, change crops that are planted in those areas.

4. Conclusion

A suitability map was created based on the approach that was adopted. It is shown that there can be suitable areas and unsuitable areas for crops in Taita Hills and it doesn't imply that farmers in unsuitable areas cannot grow crops in their farms but rather this study helps them to be aware of the environmental conditions and its impacts that may arise with the varying climate conditions in the future. It is a tool that can be used to plan and manage agricultural activities for a better yield.

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A computer-based vision systems for automatic identification of plant species using kNN and genetic PCA

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ABSTRACT

Precision farming involves integration of different areas of disciplines to lower production costs and improve productivity. One major arm of precision farming or agriculture is the development of computer-based vision systems for automatic identification of plant species. This work involves application of k Nearest Neighbour (kNN) and genetic principal component analysis (GA-PCA) for the development of computer-based vision systems for automatic identification of plant species. As the first contribution, several image descriptors were extracted from the images of plants found in the Flavia dataset. Lots of these image features are affine maps and amalgamation of such massive features in one study is a novel idea. These descriptors are Zernike Moments (ZM), Fourier Descriptors (FDs), Lengendre Moments (LM) Hu 7 Moments, Texture, Geometrical properties and colour features. The GA-PCA (1907 x 41) feature space improved the classification accuracy of kNN from 84.98% to 88.75%.

1. Introduction

Plant species identification is traditionally carried out by manual matching of the plant's features, relating to components of the plant, such as leaves, flowers, and bark, against an atlas (Meeta, 2012) and (Abdul, Lukito, Adhi and Santosa, 2012). According a survey (Babatunde, Armstrong, Leng and Diepeveen, 2015) attempts to automate this process have been made, using features of plants extracted from images as input parameters to various classifier systems. This work further examines the application of genetically selected principal components combined with k Nearest Neighbor (kNN) algorithm. The main strength of this article is the application of a GA to automatically select the minimum number of principal components needed for optimal accuracy based on the available dataset.

2. Literature Reviews

Several plant species recognition systems have been developed based on various features and classifiers. Many of these works were based on artificial neural networks (ANN) as Machine Learning Models due to their adaptability and scalability. Table 1 below shows some recent works on computer-based vision systems for automatic identification of plant species. A report on their weaknesses are shown in the last column. A deeper literature reviews on recent works on computer-based vision

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systems for plant species identification can be found in the paper (Babatunde, Armstrong, Leng & Diepeveen, 2015).

Table 1. Some existing and recent works on plant recognition systems

Author	**Techniques**	**Weaknesses (comments)**
Zalikha (et al, 2011)	Image Pre-Processing, Moment Invariants, General Regression Neural Network (GRNN).	This work needs optimization of GRNN and more features
Wu (et al, 2007)	Probabilistic Neural Network (PNN), Image pre-processing, Principal Component Analysis (PCA).	The features used are not enough to ensure improved accuracy across large dataset. Moments and colour features should be included. The parameter of PNN also needs to be optimized.
Panagiotis, T. (2005).	Fuzzy Logic Selection, Neural Networks, image pre-processing, principal component analysis.	More features are needed to improve this work.
Valliammal, N., & Geethalakshmi, S. N. (2011)	Fuzzy Segmentation, image preprocessing, wavelet transformation, leaf image moments	More features needed.
Jyotismita, C., & Ranjan, P. (2011	Thresholding method, H-Maxima transformation, Moment-invariants, Centroid-Radii and Neural Networks classifiers	More features and optimization of the ANN classifier used is needed to improve this work.

3. Methodology

This section discusses the adopted methodology in designing the proposed model (kNN-GA-PCA) for automatic identification of leaves. The used dataset is detailed in section 3.1, while section 3.2 discusses Principal Component Analysis (PCA) which was used for both feature transformation and dimensionality reduction. Genetic Algorithm and k Nearest Neighbour are detailed in section 3.3 and 3.4 respectively. The proposed approach includes image acquisition, image pre-processing, image segmentation, feature extraction, automatic selection of number of principal components by GA and image classification.

3.1 Data set

The source of images of leaves used in this study is images of leaves found in the Flavia dataset which is publicly available (Wu et al., 2007). The Flavia dataset is a constrained set of leaf images taken against a white background and without any stem present. The species in the dataset have a varying number of instances as shown (Babatunde, Armstrong, Leng & Diepeveen, 2014a, 2014b). The dataset has 1907 images of 32 species of plants. The proportion of classes in the Flavia dataset is shown in Figure 1. The complete feature space for this work comprises ZMs, FDs, Lengendre Moments, Hu 7 Moments, Texture, Geometrical properties and colour features which are extracted from the Flavia dataset as shown in Table 2 below.

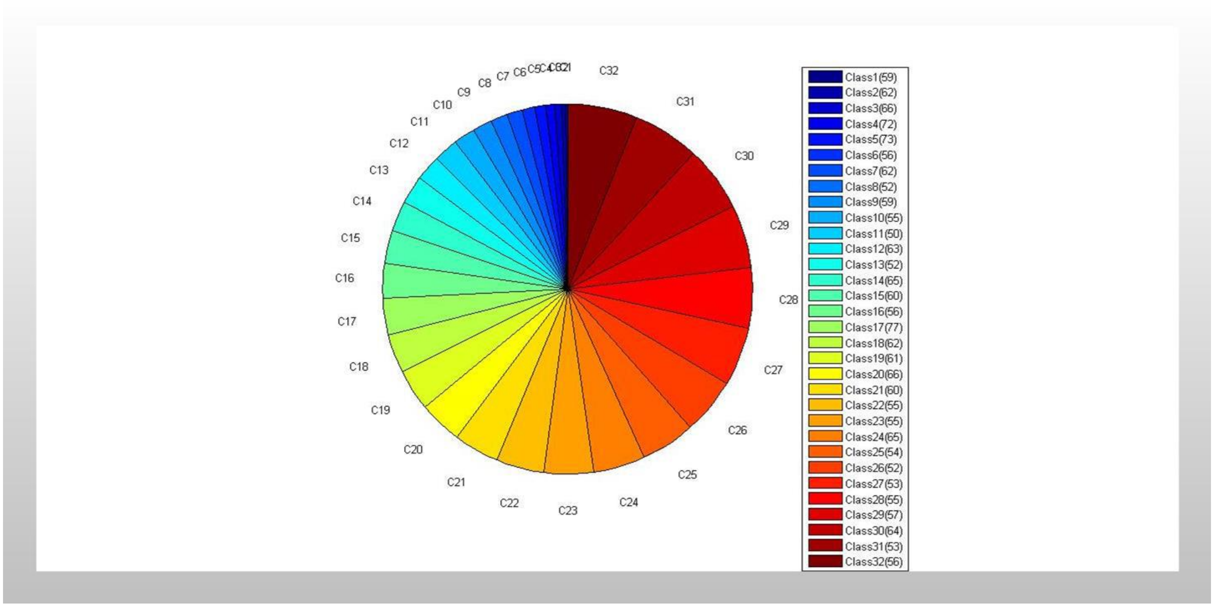

Figure 1. Proportion of plant species in the Flavia dataset

Table 2. 112 Features in the extract from the Flavia dataset

SN	Descriptor	Feature Index	Descriptor Cardinality
1	Zernike Moments (ZM)	$F_{01}, F_{02}, \dots, F_{20}$	20
2	Legendre Moments(LM)	$F_{21}, F_{22}, \dots, F_{40}$	20
3	Hu 7 Moments (Hu7M)	$F_{41}, F_{42}, \dots, F_{47}$	7
4	Texture Features (TF)	$F_{48}, F_{49}, \dots, F_{69}$	22
5	Geometric Features (GF)	$F_{70}, F_{71}, \dots, F_{79}$	10
6	Fourier Descriptors (FD)	$F_{80}, F_{81}, \dots, F_{100}$	21
7	Colour features (CF)	$F_{101}, F_{102}, \dots F_{112}$	12

3.2 Principal Component Analysis (PCA)

PCA is a mathematical procedure (orthogonal transformation from applied linear algebra) that transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated variables called the **principal components**. PCA is a dimensionality reduction technique and is useful for dimension reduction when the transformed features have a descriptive power more easily ordered than the original features. It's used in selecting a subset of variables from a large dataset, based on which the original variables have the highest correlations with the principal component. In other words, PCA seeks a linear combination of variables so that the maximum variance can be extracted from the variables. In terms of geometry, PCA is a rotation of the axes of the original variable coordinate system to new orthogonal axes, called principal axes, so that the new axes coincide with directions of maximum variation of the original observations. The property of the maximum variation of the projected points defines the first principal axis and it's the line or direction with maximum variation of the projected values of the original data points. These projected values are called principal component scores (Cambell & Atchlev, 1981). It should be noted that each principal component is a linear combination of the original variables and all the principal components are orthogonal to each other, so there is no redundant information. Thus, PCA is both feature transformation and reduction technique. The PCA accepts a dataset and rotates it in such a way that the maximum variability can be visible. The operation of PCA is given as follows:

1. **Given a dataset** $\{x_n\}, n = 1(1)N$, and x_n is a N-dimensional vector, (N = 112 for this study)
2. **Task** ?: To project the given data onto an M-dimensional subspace, where M < N , and M, N are positive integers.
3. **Assumption**: The projection is assumed to be represented as

$$y = Ax \quad \text{.......(1)}$$

where

$$A = [u_1^T, u_2^T, u_3^T, ..., u_M^T] \quad \text{.......(2)}$$

and

$$u_i^T u_i = 1 \text{ for } i = 1(1)M \quad \text{.......(3)}$$

The objective now is to maximize the variance of y_n , which is the trace of the covariance of matrix H_y of y_n . Therefore the actual objective now is to find the **maximum of TRACE** (H_y) where

$$H_y = \frac{1}{N}\sum_{n=1}^{N}(y_n - \bar{y})^T \quad \text{.......(4)}$$

and

$$\bar{y} = \frac{1}{N}\sum_{n=1}^{N} y_n \quad \text{.......(5)}$$

If we assume H_x to be the covariance matrix of x_n and since

$$trace\ (H_y) = trace\ (AH_x A^T) \quad \text{.......(6)}$$

the Langrangian multiplier and derivatives gives

$$H_x u_i = \lambda_i u_i \quad \text{.......(7)}$$

where u_i is the largest vector of H_x which corresponds to the ith largest eigenvalue. The first 33 instances of the first 14 principal components of the features derived from the Flavia dataset are given Figure 2. A 2D and 3D plot which allows you to visualize the absolute value and sign of each variable's contribution to the first two or three principal components, and how each observation is represented in terms of components shown in Figures 3, 4 & 5.

	PCA1	PCA2	PCA3	PCA4	PCA5	PCA6	PCA7	PCA8	PCA9	PCA10	PCA11	PCA12	PCA13	PCA14
1	0.0220	0.0062	0.0091	0.0034	0.0354	-0.0241	-0.0027	-0.0085	-0.0146	0.0229	-0.0096	-0.0032	-0.0128	0.0259
2	0.0163	0.0511	0.1338	0.1000	0.0589	0.1984	0.0242	-0.0043	0.0332	0.0425	0.0034	-0.0518	0.0185	-0.0329
3	0.0153	0.0028	0.0148	0.0028	-0.0086	0.0024	-0.0310	0.0772	0.0217	0.1103	-0.0030	-0.0734	-0.0145	0.0124
4	0.0199	0.0033	0.0178	-0.0064	0.0284	-0.0082	0.0012	0.0049	0.0133	0.0237	0.0020	-0.0358	0.0208	-0.0037
5	0.0143	-0.0080	0.0360	-0.0151	0.0189	-0.0123	0.0021	0.0079	0.0111	0.0145	0.0101	-0.0308	0.0279	-0.0024
6	0.0199	0.0014	-0.0041	-0.0073	-0.0067	0.0138	-0.0293	0.0932	0.0136	0.0644	-0.0084	-0.0437	-0.0299	0.0419
7	0.0191	-0.0013	0.0190	-0.0056	0.0292	-0.0185	4.2073e-04	-0.0048	-0.0175	0.0068	-0.0142	0.0015	-0.0209	0.0322
8	0.0200	0.0027	0.0185	-0.0055	0.0314	-0.0111	0.0034	-0.0072	-0.0194	0.0113	-8.1569e-...	0.0019	-0.0176	0.0304
9	0.0197	-0.0018	0.0137	-0.0100	0.0285	-0.0130	7.0806e-04	0.0022	-2.9923e-...	0.0144	0.0072	-0.0149	0.0121	0.0028
10	0.0173	-0.0153	0.0127	-0.0144	0.0190	-0.0057	-0.0118	0.0511	0.0720	0.0129	-0.0063	-0.0243	0.0346	-0.0077
11	0.0164	-0.0105	0.0254	-0.0225	0.0208	-0.0048	0.0065	0.0026	-0.0100	-0.0060	0.0079	8.5887e-04	-0.0119	0.0283
12	0.0187	-0.0074	0.0126	-0.0273	0.0266	-0.0061	0.0093	-0.0042	-0.0163	0.0062	0.0241	0.0042	-0.0153	0.0292
13	0.0180	-0.0073	0.0156	-0.0056	0.0347	-0.0050	-0.0054	0.0196	0.0216	0.0068	0.0042	0.1021	0.0316	0.0029
14	0.0182	-0.0018	0.0232	-0.0063	0.0281	-0.0137	0.0017	-0.0045	-0.0149	0.0078	-0.0087	0.0057	-0.0134	0.0260
15	0.0201	0.0137	0.0067	-0.0094	-0.0134	0.0059	-0.0265	0.0985	0.0099	0.0498	-0.0363	-0.0320	-0.0274	0.0517
16	0.0217	-0.0095	-7.4829e-...	-0.0049	0.0392	-2.9437e-...	3.8089e-04	-0.0098	-0.0177	0.0147	0.0077	-1.9305e-...	-0.0242	0.0301
17	0.0130	-0.0089	0.0208	-0.0038	-0.0140	-0.0026	-0.0337	0.0917	0.0157	0.0695	-0.0111	-0.0501	-0.0317	0.0413
18	0.0182	0.0015	0.0233	-0.0052	0.0348	-0.0059	-0.0021	0.0190	0.0250	0.0156	-0.0019	0.0862	0.0039	0.0244
19	0.0208	-8.7920e-...	-0.0118	0.0029	-0.0027	0.0060	-0.0357	0.0896	0.0140	0.0721	-0.0129	-0.0507	-0.0272	0.0364
20	0.0163	-0.0045	0.0062	-0.0021	-0.0102	-0.0060	-0.0353	0.0902	0.0145	0.0729	-0.0216	-0.0526	-0.0285	0.0377
21	0.0163	0.0047	0.0226	0.0025	-0.0153	0.0079	-0.0305	0.0982	0.0140	0.0466	0.0106	-0.0269	-0.0294	0.0526
22	0.0175	-0.0030	0.0229	-0.0073	0.0322	-0.0045	-0.0023	0.0182	0.0178	0.0040	0.0079	0.1156	0.0212	0.0089
23	0.0186	-6.1982e-...	0.0229	-0.0017	0.0320	-0.0127	0.0015	-0.0081	-0.0143	0.0187	0.0211	-7.1950e-...	-0.0204	0.0266
24	0.0179	-0.0048	0.0212	-0.0072	0.0304	-0.0149	0.0014	-0.0074	-0.0169	0.0146	-0.0023	0.0018	-0.0199	0.0280
25	0.0188	-0.0033	0.0175	-0.0078	0.0310	-0.0170	0.0011	-0.0074	-0.0183	0.0141	-0.0150	0.0021	-0.0198	0.0279
26	0.0178	-0.0097	0.0187	-0.0046	0.0313	-0.0116	-9.6612e-...	-0.0055	-0.0142	0.0106	-0.0069	-7.5025e-...	-0.0168	0.0294
27	0.0180	-0.0043	0.0259	-0.0055	0.0270	1.2694e-04	0.0030	3.0358e-04	-0.0122	-0.0028	0.0068	0.0035	-0.0115	0.0278
28	0.0202	-0.0024	0.0079	-0.0196	0.0332	-0.0092	0.0070	-0.0101	-0.0177	0.0234	0.0024	0.0010	-0.0189	0.0264
29	0.0191	0.0013	0.0223	-0.0030	0.0299	-0.0171	0.0018	-0.0078	-0.0195	0.0106	0.0119	0.0018	-0.0231	0.0332
30	0.0202	-0.0027	0.0126	-0.0076	0.0321	-0.0096	0.0022	-0.0064	-0.0186	0.0077	-0.0072	0.0013	-0.0227	0.0348
31	0.0195	-0.0047	0.0065	-0.0069	0.0368	-0.0122	-0.0066	0.0166	0.0165	0.0139	-0.0111	0.1041	0.0365	-0.0061
32	0.0196	-0.0040	0.0094	-0.0110	0.0356	-0.0047	-0.0028	0.0187	0.0200	0.0087	-0.0071	0.1007	0.0196	0.0187
33	0.0182	-0.0028	0.0208	-0.0071	0.0338	-0.0017	-0.0022	0.0197	0.0228	0.0063	-0.0081	0.0979	0.0057	0.0250

Figure 2. The first 14 principal component of the original feature set

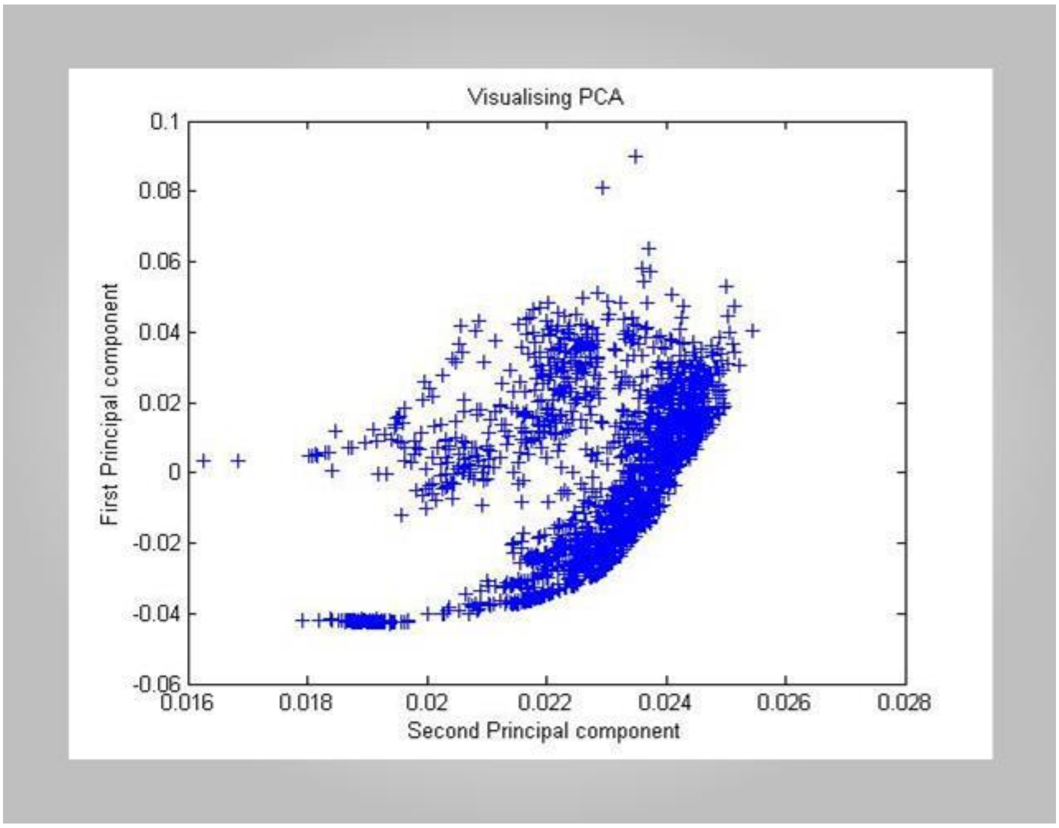

Figure 3. Visualization of two PCA axes

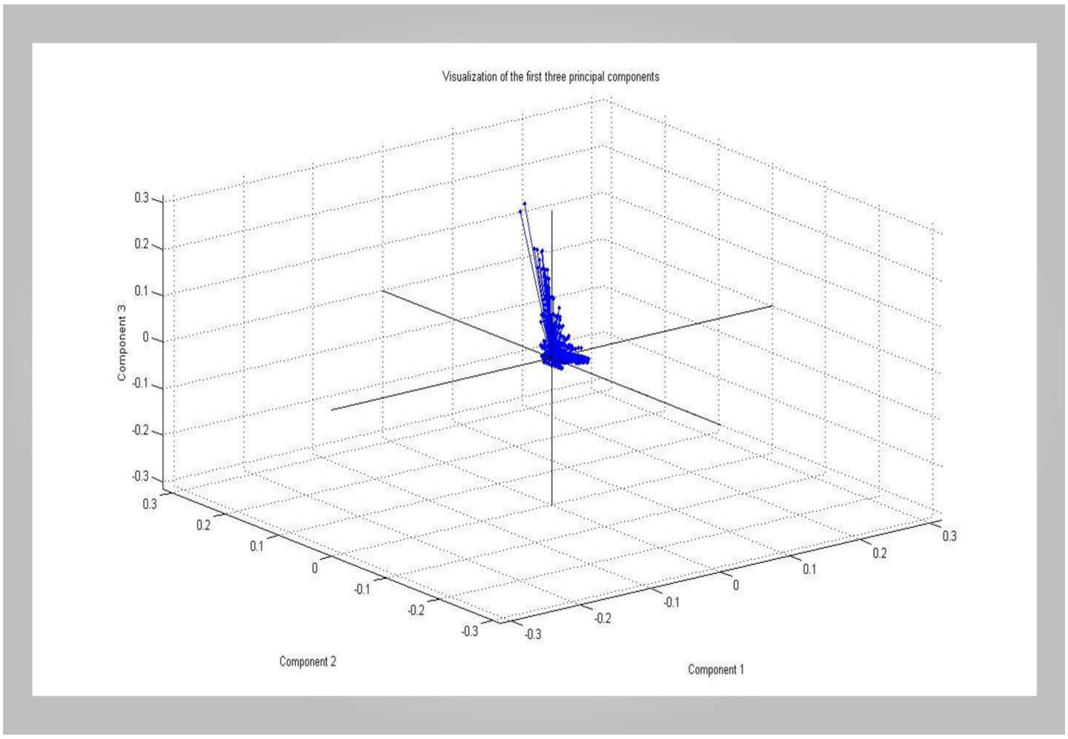

Figure 4. A 3D view of the first three principal components

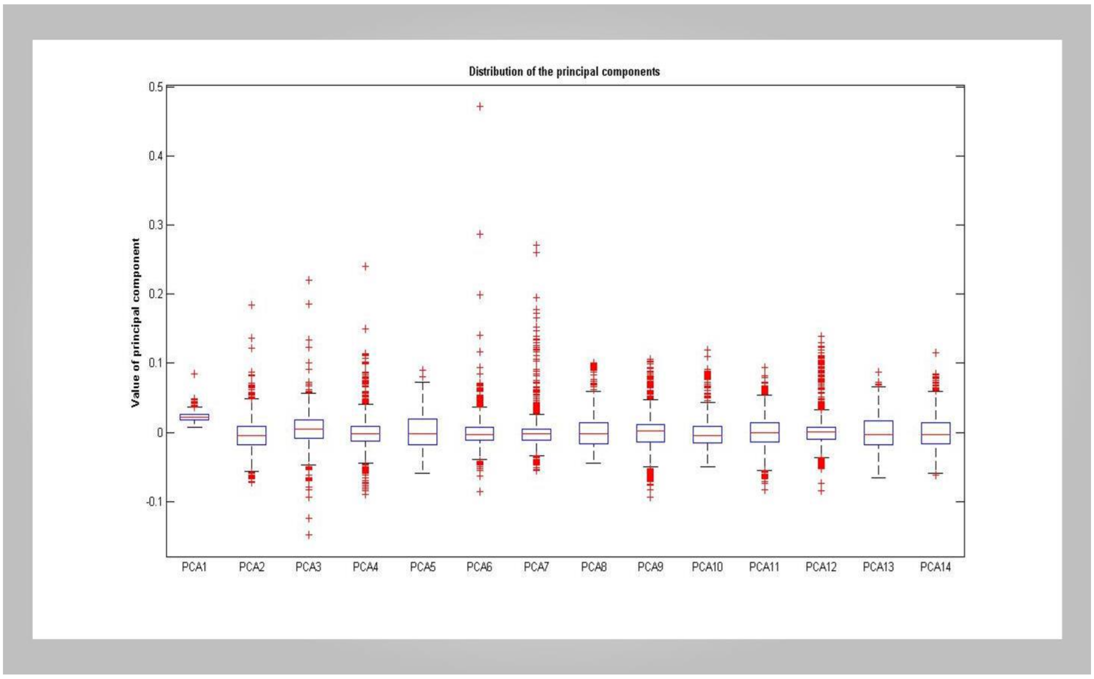

Figure 5. Distribution of the principal components

3.3 Genetic Algorithm (GA)

Genetic Algorithms (GA) can be defined as population-based and heuristic algorithmic searching methods that mimic natural evolution process of man (Melanie, 1999; Tian, Hu, Ma & Ha, 2012; Babatunde, Armstrong, Leng & Diepeveen, 2014d, 2014a, 2014b). GA iteratively employ the use of one population of chromosomes (solution candidates) to get a new population using a method of natural selection combined with genetic functions such as crossover and mutation (in the similitude of Charles Darwin evolution principle of reproduction, genetic recombination, and the survival of the fittest). In comparative terminology to human genetics, chromosomes are the bit strings, gene is the feature, allele is the feature value, locus is the bit position, genotype is the encoded string, and phenotype is the decoded genotype (Sivanandam & Deepa, 2008). The fitness of each chromosome is evaluated using a function commonly referred to objective function or fitness function. In other words, the fitness function (objective function) reports numerical values which are used in ranking the chromosomes in the population. The fitness function used for both GA and PSO is given as Equation 2. The detailed description of the GA can be found in the companion paper of Babatunde, Armstrong, Leng and Diepeveen (2014b).

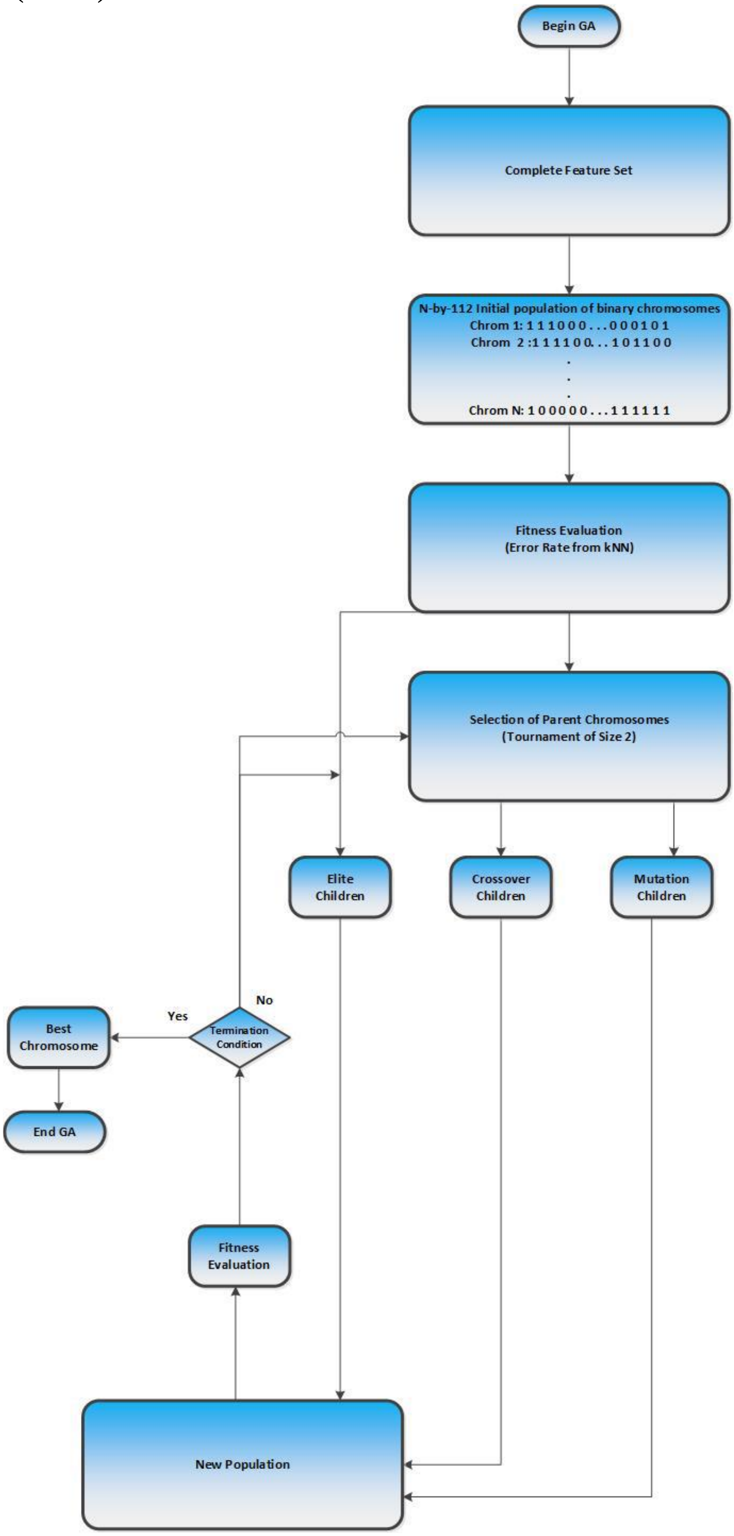

Figure 6. GA-Based Feature Selection ((Babatunde, Armstrong, Leng and Diepeveen, 2014b))

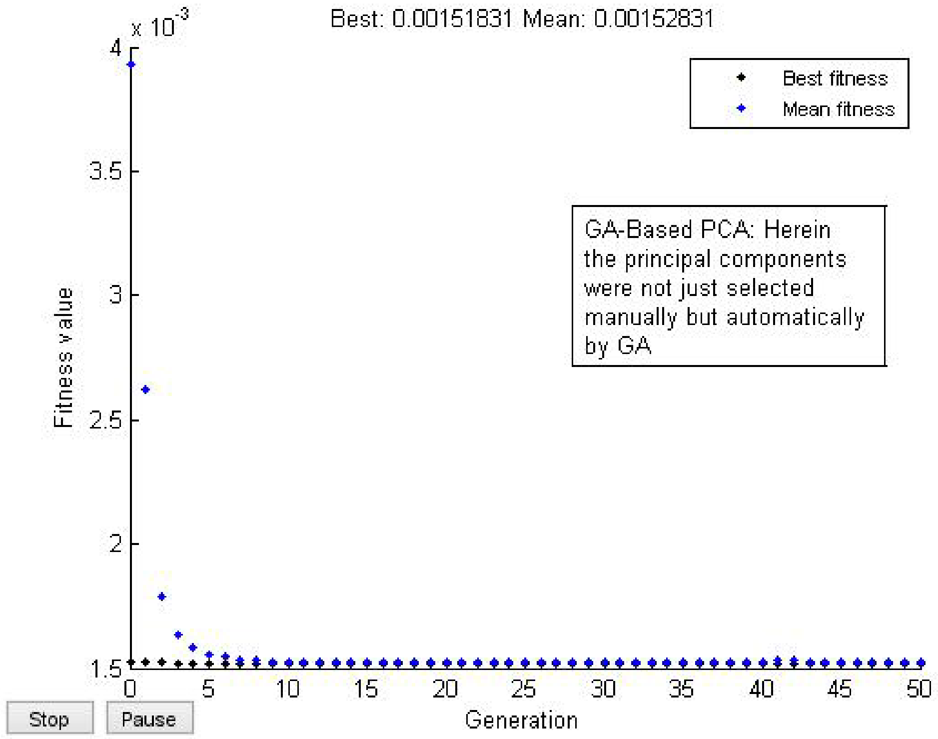

Figure 7. Simulation diagram on genetically selected principal components

3.4 K Nearest Neighbour

The kNN is metric-based algorithm that solves classification problem by looking for the shortest distance between the test data and training sets in the feature space. The distance is generally computed in Pythagorean sense (by finding the square root of the sum of differences). Suppose the training set, using the features in Table 2 is defined as

$$x = \begin{bmatrix} x_{11} & x_{12} & x_{13} & \ldots & x_{1N} \\ x_{21} & x_{22} & x_{23} & \ldots & x_{2N} \\ x_{31} & x_{32} & x_{33} & \ldots & x_{3N} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{M1} & x_{M2} & x_{M3} & \ldots & x_{MN} \end{bmatrix} \qquad (8)$$

where M = 1907, the number of observations in these dataset. The number of features here is N. The kNN algorithm computes Euclidean distance between test data x_{TEST} and all entries in the training sets and then finds the nearest point (shortest distance) from the training set to the test set as:

$$D(x_{TEST}, x_m) = \sqrt{\sum_{m=1}^{M} (x_{TEST} - x_m)^2} \qquad (9),$$

where $m = 1,2,3..., M$. The kNN considers only the k nearest neighbours denoted as $\{x_1, \ldots x_k\}$ as the member(s) of the set (a normed linear space).

$$kNNSpace = \{x_j \mid d(x, x_i) \le d(x, x_j)\} \qquad (10)$$

The kNN rules involves classifying a test sample, say, x, by assigning it to the most frequently represented among the k nearest samples. The diagram in Figure 8 taken from Mathworks (2013) illustrates 3 Nearest Neighbours as they are the three shortest distances reported. A similar figure generated from this study, showing first 18 neighbours of a test sample from the Flavia dataset is shown in Figure 9. The kNN counts each category m in the class information and the report classification results based on the expression

$$\arg\max(count(x_m)) \qquad (11)$$

subject to

$$\sum_{i=1}^{M} count(x_m) = class \qquad (12)$$

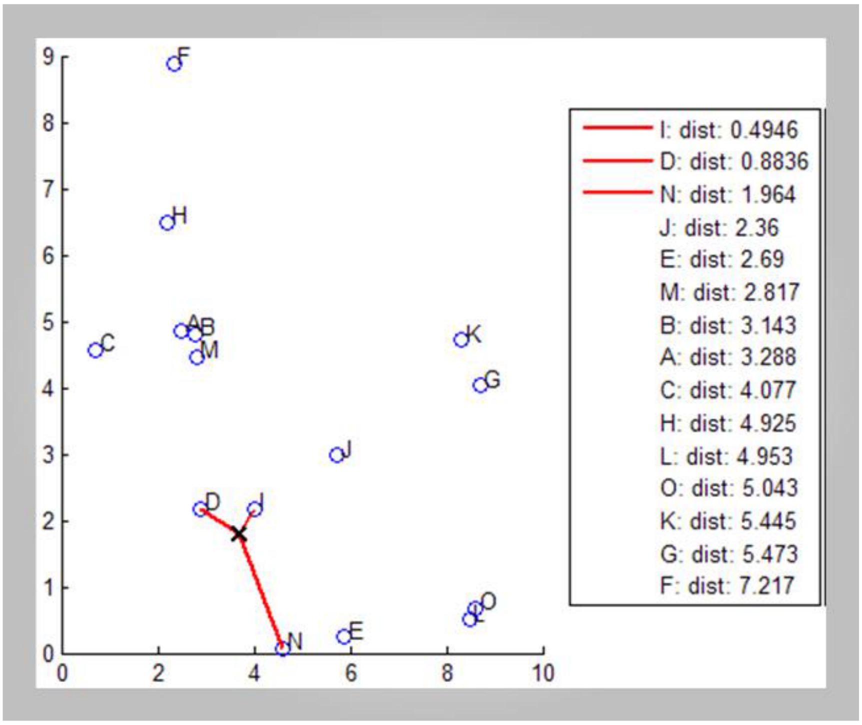

Figure 8. A diagram showing k = 3 nearest neighbours

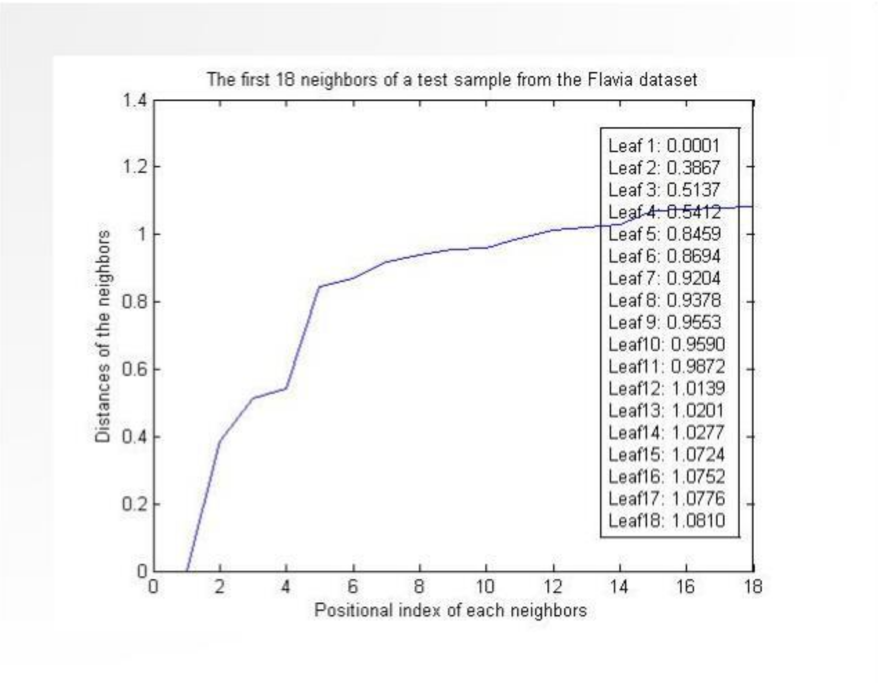

Figure 9. A diagram showing k = 18 nearest neighbours

4. Experimental Design and validation

The research approach used in this work is shown in Figure 10. The classification model was kNN. The different distance metric that can be used with the kNN are Euclidean, standard Euclidean, Mahalanobis, Minkowski, Chebychev, Cosine, Correlation, Jaccard and Spearman distance. The choice distance metric for this study is Euclidean distance. A sample screen shot of the kNN-based classification model. The feature space generated from the Flavia dataset discussed in section 3 was partitioned into two disjoints set (training and test set) via 10-fold cross validation as shown in Figure 11. The feature space (PCA space) itself was a reduced feature space as GA was used to automatically select the number of principal components (PC) finally used. The number of PCs was 41. The implementation was done in MATLAB 2013.

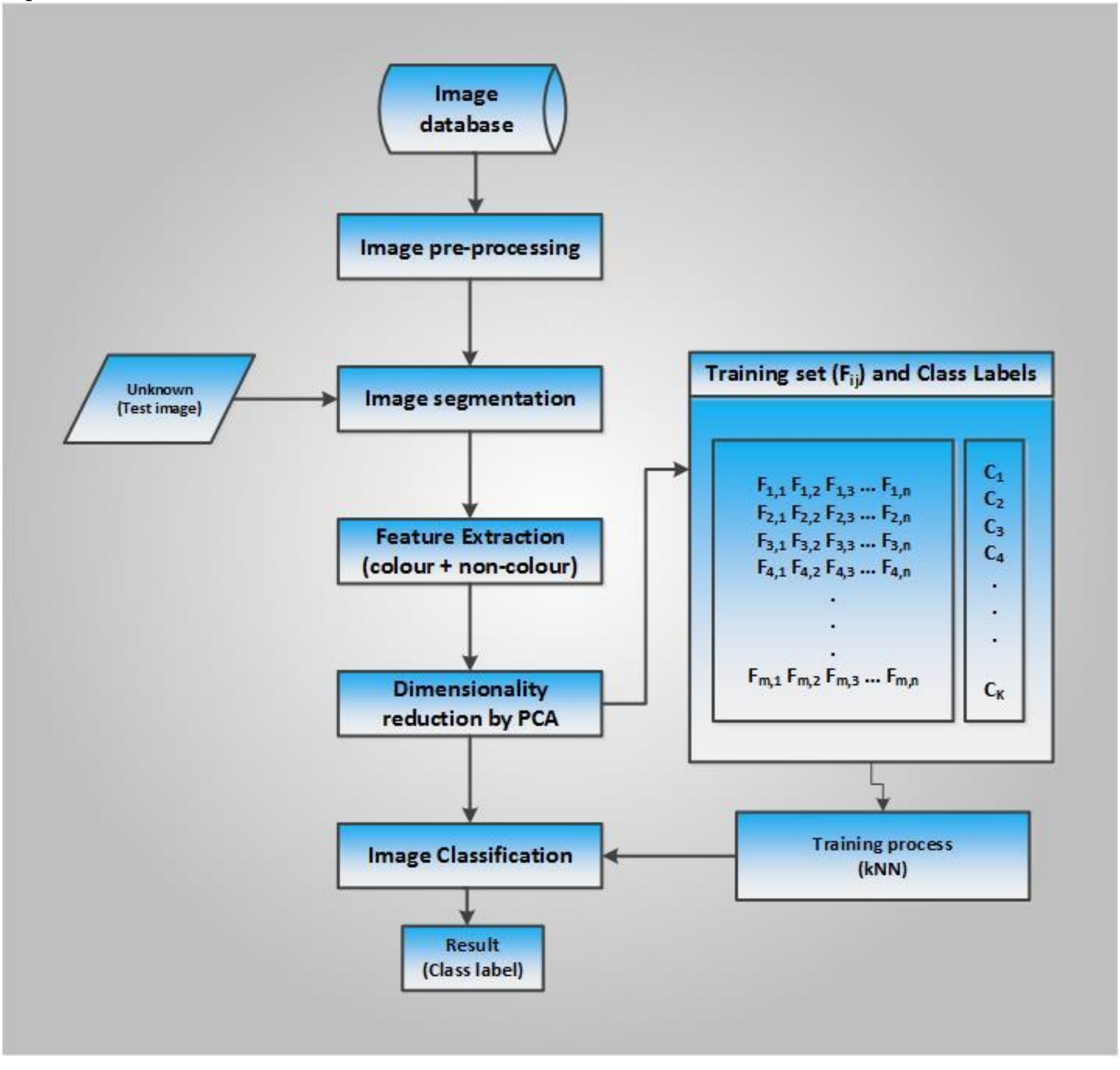

Figure 10. A research approach on computer-based vision system for automatic identification of plant species.

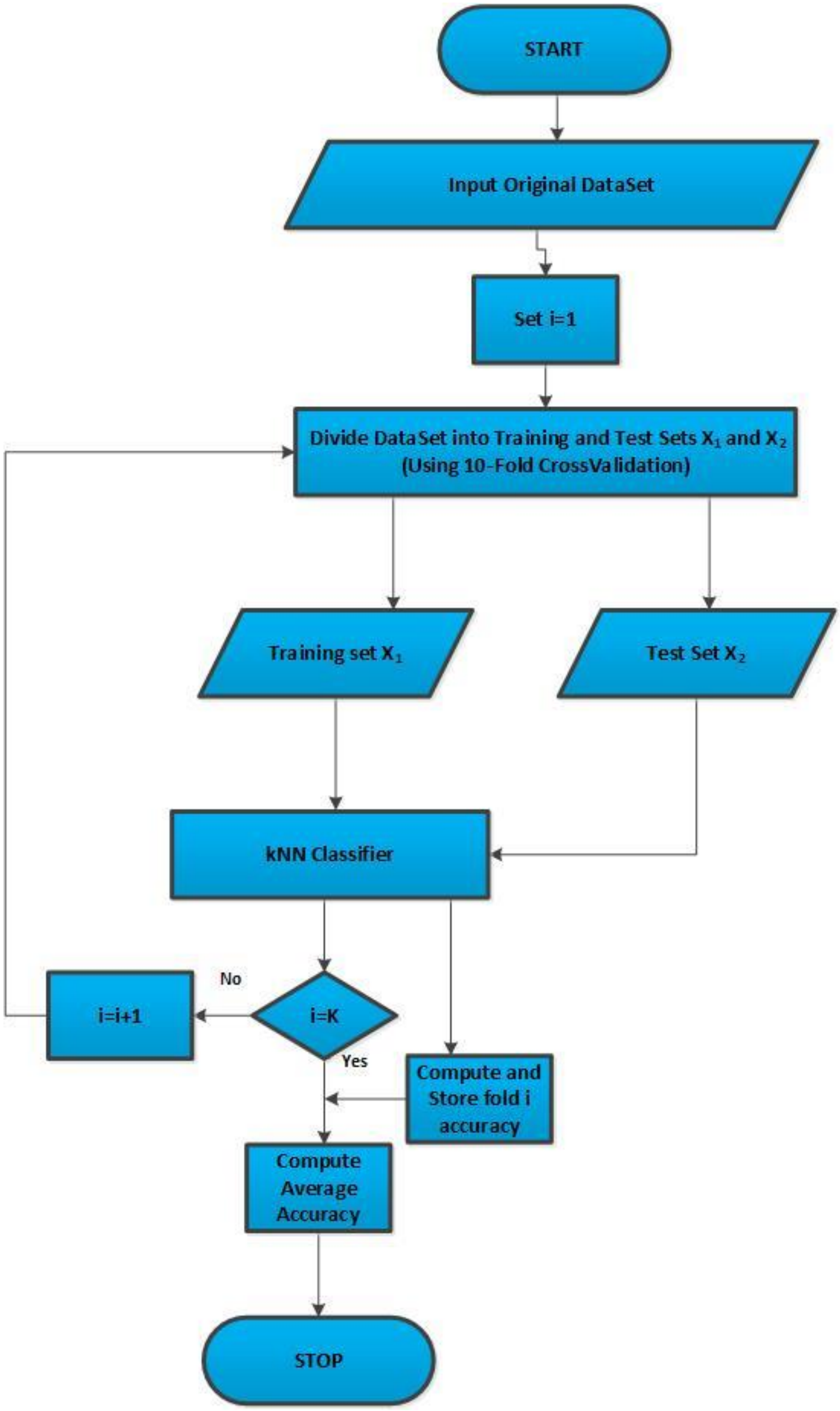

Figure 11. 10-fold cross validation partition based on kNN classifier (adapated from Babatunde, Armstrong, Leng & Diepeveen, 2014c)

Table 3. Experimental results

S/N	Classification model	Accuracy
1	kNN + Original feature set	84.98%
2	kNN + GA_PCA-based features	88.75%

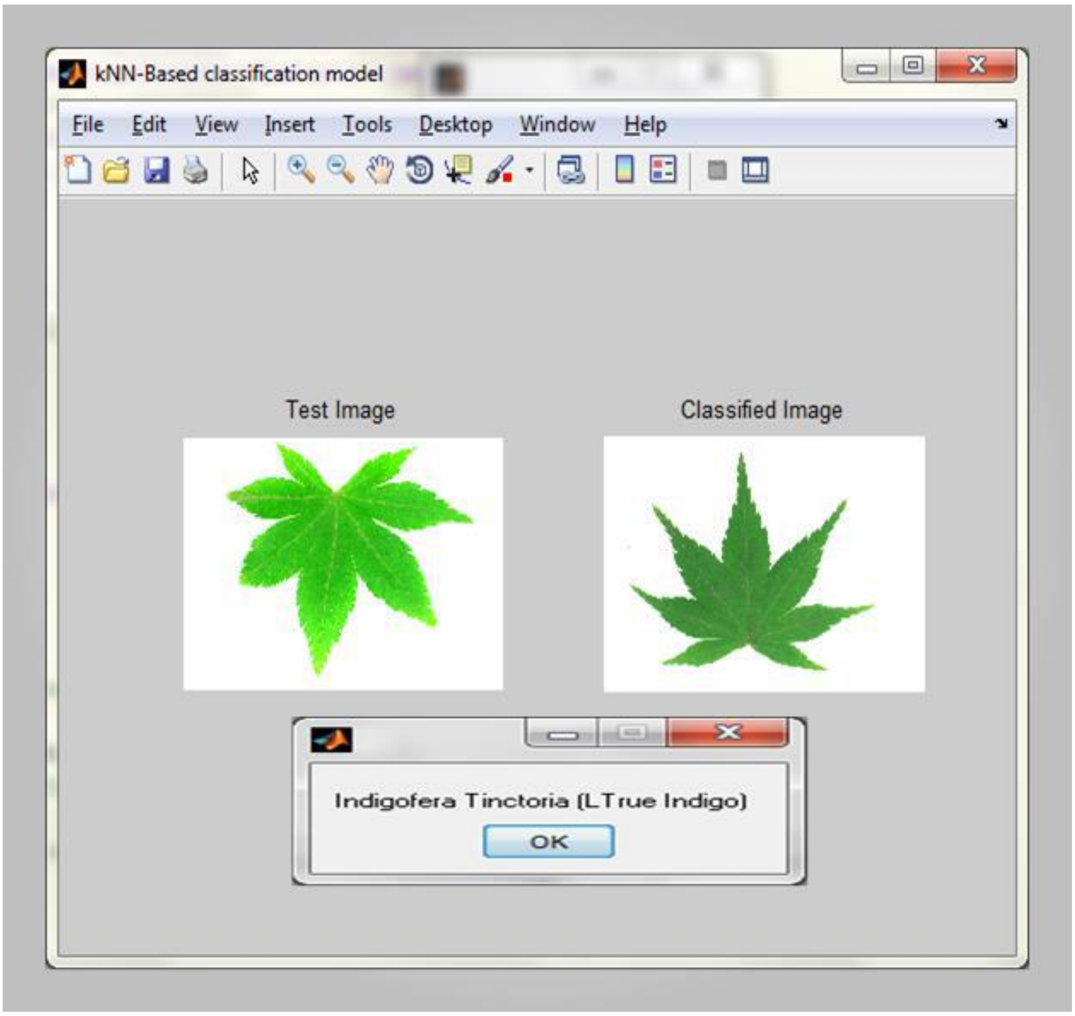

Figure 11. kNN-based classification model

6. Conclusion

Precision agriculture is a multidisciplinary field, integrating various disciplines such as agronomy, computer science, statistics, economics, environmental science, automatic control, telecommunications and microelectronics. The purpose of this paper is to emphasize the role of image processing methods in precision agriculture. This work centers on the application of kNN and genetically selected principal components (PCs) for the development of computer-based vision systems for the identification of plant species. The major new idea involved in this work is the application of GA to automatically select the minimum PC needed to achieve improved accuracy. The original feature space was a 1907 x 112 matrix of real numbers (PCs) while the genetically selected PCs were a 1907 x 41 matrix of real numbers (PCs). The approach in this work can be embedded in agricultural robots in distinguishing weeds from crops. This work can be used in automatic identification of farm animals and other applications involving image processing techniques.

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Use of computer vision to determine leaf damage caused by *Diaphania hyalinata* in Santiago del Estero, Argentina

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A B S T R A C T

Diaphania hyalinata (L.) is a major pest of agriculture for cucurbits that causes different percentages of defoliation. In this context and to determine precisely the consumed area during the larval stage, we developed a method that uses computer vision techniques. Programs use digitized images of the leaves before and after inserting the larvae to determine the consumed area. The programs work with binarized and thresholded images, first processing the leaf without damage, then the one that presents decrease in the surface, and the damaged area is found by relating the constituent elements of each image. Resulting values were similar to those mentioned and measured for this specie using other techniques. It is considered an important contribution for its accuracy and short time spent in processing.

1. Introduction

Our studies were done at the irrigation area of Santiago del Estero, located in North-West Argentina, where small farm producers work on diversified productive unities, locally known as “cercos”, and mainly use the association corn (*Zea mays* L.) – butternut squash *Cucurbita moschata* (Duchesne ex Lam). This crop growing system is probably inherited from Central America “milpas” when Incas extended along the Pacific coast of South America. The “cerco” system refers to a complex combination of agronomic practices, crop associations and rotation sequences. Ancient in origin, the system is now practiced in ways that vary widely from one agro-environment or cultural context to another. The most fundamental components of the system are a cluster of maize, bean, and squash landraces planted in association. Several maize landraces are typically grown, some more extensively than others, each corresponding to the specific consumption practices, soil characteristics and agronomic needs of the farm and farm family (Birol, Villalba & Smale, 2009). Milpa or cerco systems let take maximal advantage of the environmental conditions, as documented by Simmons (1986), Montes-Hernández, Merrick & Eguiarte (2005), Letourneau (1986) and Ranere et al. (2009) inter alia.

Among the cucurbitaceae family, species of *Cucurbita* genre are essential in Santiago del Estero province; nevertheless plague occurrence causes damage to crops and its control is a factor of

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increasing production costs (Lira Saade & Montes-Hernández, 2005). For this reason, knowledge and management of insects of this species are important for future plantation development.

Diaphania hyalinata (L.) (Lepidoptera; Pyralidae), also known as melonworm, is mentioned as squash main plague concerning butternut squash crops. Melonworm feeds on leaves and occasionally on the flowers and surface of fruit. Summer and winter squash are its preferred hosts. High populations will defoliate plants leaving nothing but leaf veins. On less preferred hosts like cantaloupe, larvae may feed on the surface of the fruit, leading to the name rindworm (Pozo, 2003).

In the area of horticultural production in Santiago del Estero, populations occur almost every year in high number, causing considerable damage. Generally, farmers apply insecticides several times to control the plague but with low effectiveness due to bad timing. The main reason to this is lack of knowledge and/or poor information about the species biology and population behavior under the agro ecological conditions for the province.

Studying the damage caused by larvae on leaf consumption is important as it will provide helpful information to establish operating guides for plague control. Metcalf and Luckmann (1992) indicate that almost all plants can tolerate a considerable defoliation without yield reduction yet, at the same time, that tolerance varies with stage of plant growth, overall plant vigor and the adequacy of growing conditions such as temperature, moisture and soil fertility (Metcalf and Luckmann, 1992). From this, it is crucial to make quantitative studies of damage versus reduction in crop yields to establish tolerable damage thresholds.

This work aims to evaluate the area of leaf damage caused by *D. hyalinata* using computer vision techniques.

1.1 *Diaphania hyalinata* (L.)

D. hyalinata L. is commonly known as melonworm moth and occurs throughout most of Central and South America and the Caribbean.

Melonworm is restricted to feeding on cucurbits. Both wild and cultivated cucurbits may be attacked. Summer squash and the winter squash species are good hosts. Pumpkin is of variable quality as a host, probably because pumpkins have been bred from several *Cucurbita* species. The *Cucumis* species, cucumber, gerkin, and cantaloupe, are attacked but not preferred. Watermelon is a rare host.

In about 30 days the melonworm can complete its life cycle: egg, larva (total development of about 14 days), pupa and adult (butterfly)

Figure 1 shows larvae and adult *D. hyalinata*

Figure 1. Larvae *D. hyalinata*

Figure 2. Adult *D. hyalinata* (Photo by Bob Patterson)

1.2 Leaf damage

Melonworm feeds principally on foliage, especially if foliage of a favored host plant such as summer or winter squash is available. Usually the leaf veins are left intact, resulting in lace-like plant remains. However, if the available foliage is exhausted, or the plant is a less preferred species such as cantaloupe, then the larva may feed on the surface of the fruit, or even burrow into the fruit. Growers sometimes refer to these insects as "rindworms" because they cause scars on the surface of melons. In a study of melonworm damage potential to summer squash conducted in south Florida, melonworm caused a 23 % yield loss due to foliage damage (indirect loss) and a 9 to 10% yield reduction due to fruit damage (direct loss) (McSorley and Waddill, 1982), Kelsheimer (1949), Capinera (2014).

Studying leaf damage is necessary as it will provide useful data for pest-management guides and policies.

In laboratory essays it was observed that leaf feeding began from the first and extended to fifth instar of *D. hyalinata* larvae, during which larvae remained hyperactive, both growth and feeding.

1.3 Artificial vision

Artificial vision aims to mathematically model visual perception processes and generate programs that let computers duplicate the abilities of human vision by electronically perceiving and understanding an image (Jähne and Haußecker, 2000).

Artificial vision lets automatically detect the structure and properties of a dynamic three dimensional world from bi dimensional images. These images can be monochromatic or color and can be obtained from different devices such as scanners, photographic or video cameras.

In many professional fields, including biology, technicians perform tasks that require repetitive and systematic visual analysis. Such tasks, in many cases, can be automated using artificial vision techniques. Automating these processes involves certain advantages as (a) analysis time is reduced because a computer can count thousands of items in a few seconds and (b) error is reduced, since the computer notices every object component regardless its size.

The main advantages of applying the computer vision technique include the rapid, precise, objective, efficient, consistent and non-destructive treatment, reduction of tedious and subjective human treatment, automation of mass labour-intensive operations, rapid generation of reproducible results, the ability of analyze each pixel of the surface of interest, the possibility of analyzing the whole object even if it is of small or irregular shape and of nonuniform colors and the ability of a permanent storage of any data for further analysis by keeping the picture (Kilcast, 2013).

2. Materials and methods

Observations were performed in cultured squash (*Cucurbita moschata* (Duchesne ex Lam.) (Duchesne ex Poir) in association with maize (*Zea mays*) located in the Campo Experimental of the University (Zanjón, Dpto. Capital of Santiago del Estero). Sowing was done in mid-January 2011. After the emergence of maize seedlings thinned was performed to achieve a density of approximately 6-7 plants per meter.

From the moment of occurrence of populations of melonworm in cultivation plots weekly monitoring were conducted; the pupae detected, 30 were collected at random and taken to the laboratory for Agricultural Zoology of the Agronomy School, where sexing was performed. Copies of each sex were placed in separate vials.

Adults (butterflies) just born were grouped in pairs, placed in wire cages lined with tulle fabric and taken to the field. Each cage was placed in a terminal bud and fixed to the floor via a bracket. Once postures were detected, daily observations were made until hatching; the newly hatched larvae were then transferred to the laboratory, placed on separate detached leaves of *C. moschata* and raised at room temperature.

The pupae obtained in the first generation were sexed and separated to begin a second generation, which was held in brood chamber at a constant temperature of 28°C and 70% RH. Tracking method was the same as the first generation.

The eggs were placed in isolation or in groups of 2 to 3, wherein the beam and on the underside of young leaves. The incubation period lasted approximately 3 days.

Daily consumed leaf area was measured in 8 leaves; for this, the images obtained through a binocular magnifying glass with an Olympus camera were digitized.

Leaf consumption by larvae in the first generation was 632.48 mm^2. During the fourth stage was when more food is consumed, which coincides with reported by Pozo (2003). Could not determine the value for the larvae of the second generation due to decay of leaf tissue, which is why only came to evaluate area consumed until the fourth.

Initially, technicians of the laboratory for Agricultural Zoology used Image Tool 3.00 (UTHSCSA, 2002) software to measure consumed area. The method was to fill empty irregular areas of the leaf with simple geometric shapes and, by adding their areas, the foliar damage was obtained. However, the results were only approximate because overlaps as well as involuntary omissions occur. Figure 3 illustrates the procedure employed. Here, the most important limitation is that the staff assigned to the tedious task of collecting the data is capable of using the necessary instruments accurately.

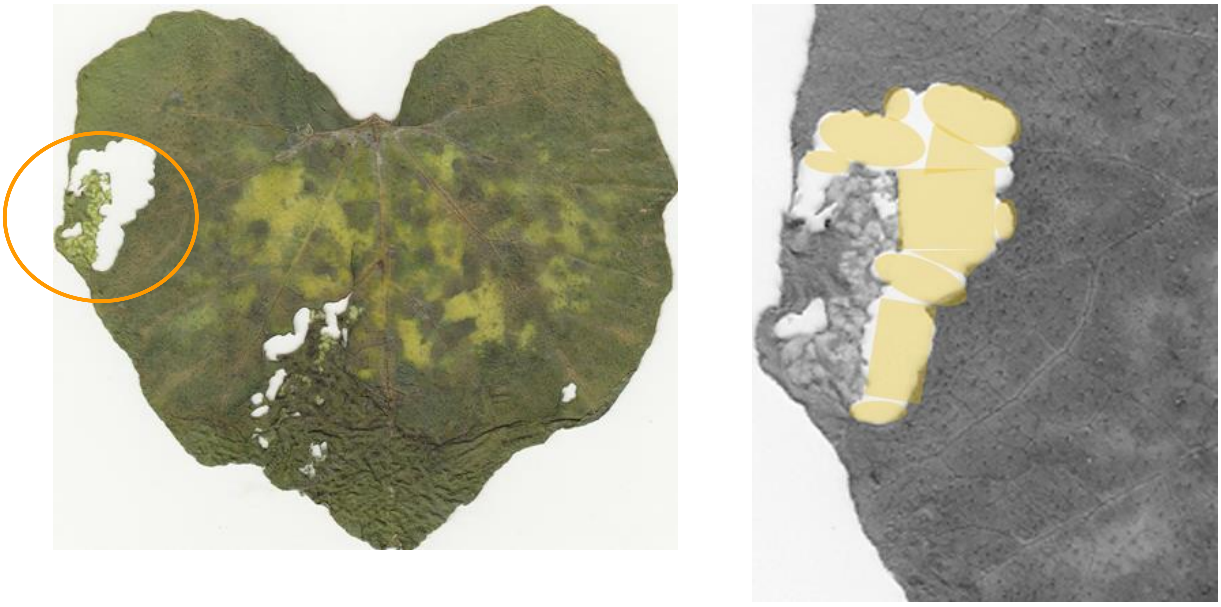


Figure 3. The result of filling empty areas with simple geometric figures shown. It can be seen that some areas are not taken into account, damaged areas overlap and, moreover, parts of the leaf which have not suffered damage have been selected

In order to get more precise results it was decided to use computer vision techniques and implement specifically designed algorithms to perform the area measurement.

Images from the leaves of *C. moschata* were digitized using a Visioneer OneTouch 8100 scanner, at constant quality (300 DPI), storing them in BMP format to avoid the distortions of compressed digitized formats. Scanned images are of variable dimension due to leaves different sizes.

A color digitized images is represented as a 3D matrix that contain values between 0 and 255 to represent colors (Figure 4). In our particular context, color information is irrelevant to the objective so the image is converted to black and white and the program works with two dimensional (2D) matrixes (Figure 5). This conversion process is called binarization and uses a threshold value to distinguish the object from the background. The resulting matrix only contains zeros (0) and one (1) values.

Figure 4. Color image

Figure 5. Binarized image

Specific algorithms were generated based on pixel neighborhood concept to determine component connection. Pixel connectivity is the way in which pixels in 2- or 3-dimensional images relate to their neighbors (Cheng, Peng & Hwang, 2009). Our work is based in 8-connected pixels: 8-connected pixels are neighbors to every pixel that touches one of their edges or corners. These pixels are connected horizontally, vertically, and diagonally. Being *p(x,y)* the pixel of interest, its neighbors ($N_8(p)$)are p(x±1,y±1). Mathematically,

$$N_8(p) = \begin{Bmatrix} (x+1,y),(x-1,y),(x,y+1),(x,y-1),(x+1,y+1),(x+1,y-1), \\ (x-1,y+1),(x-1,y-1) \end{Bmatrix}$$

The algorithm inspects the image pixel by pixel, examining those that have not been assigned to any object. A sequential path of the image matrix is performed and, for each pixel with value 1, its coordinates are added to a list. Using the concept of 8-neighborhood, the neighbors are inspected looking for those with value 1 to add them to the list. When finishing the verification of the pixels connected to the originally found, the coordinates of each of the pixels that form an object are stored.

A matrix *O* is used, with changing size throughout the execution of the program. It will contain the coordinates of the pixels that make up the various objects.

A binarized digital image is represented in a matrix *I* of *NxM* pixels, *I* runs element by element from left to right and from top to bottom. The neighbors' inspection is made taking corners and borders as special cases.

For each pixel *p(i,j)* = 1 its coordinates are entered in a list and its 8 neighbors are inspected verifying which are connected.

Each neighbor *v(k, l)* = 1 is added to matrix *O*, following pixel *p(i,j)*. At this moment, the focus will be on *v(k,l)* and its neighbors with value 1. As they are found, it is checked that had not previously selected and they are added to matrix *O*, becoming the new pixel of interest.

In order not to add replicated pixels, neither inspecting already checked pixels, each is nullified when incorporated to the list. The process is cyclic until no more connected neighbors are found. At this moment, a trajectory per row is stored (each, considered an object) and the row index for *O* is increased. The algorithm returns control to the general matrix path, the index is increased and now the new pixel of interest is *p(i, j+1)*, repeating the whole process over *I*

As previously mentioned, each list element is an object. Since the program works with a matrix with values 0 or 1, the sum of each row of the resulting array equals to the size of different objects. Flow charts of this algorithm (Figure 6) are available at *http://www.cimec.org.ar/ojs/index.php/mc/article/viewFile/3955/3872* (Larcher et.al., 2011).

The program developed resulted robust, showing high efficiency in various applications, being computational time directly proportional to the object size and having a low consumption of memory. Particularly, the subprogram that performs object extraction and counting was extensively tested.

The software tool was programmed in Matlab using a PC with Intel Core 2 Quad Q8200 processor equipped with 2 GB of RAM under a 64-bit operating system.

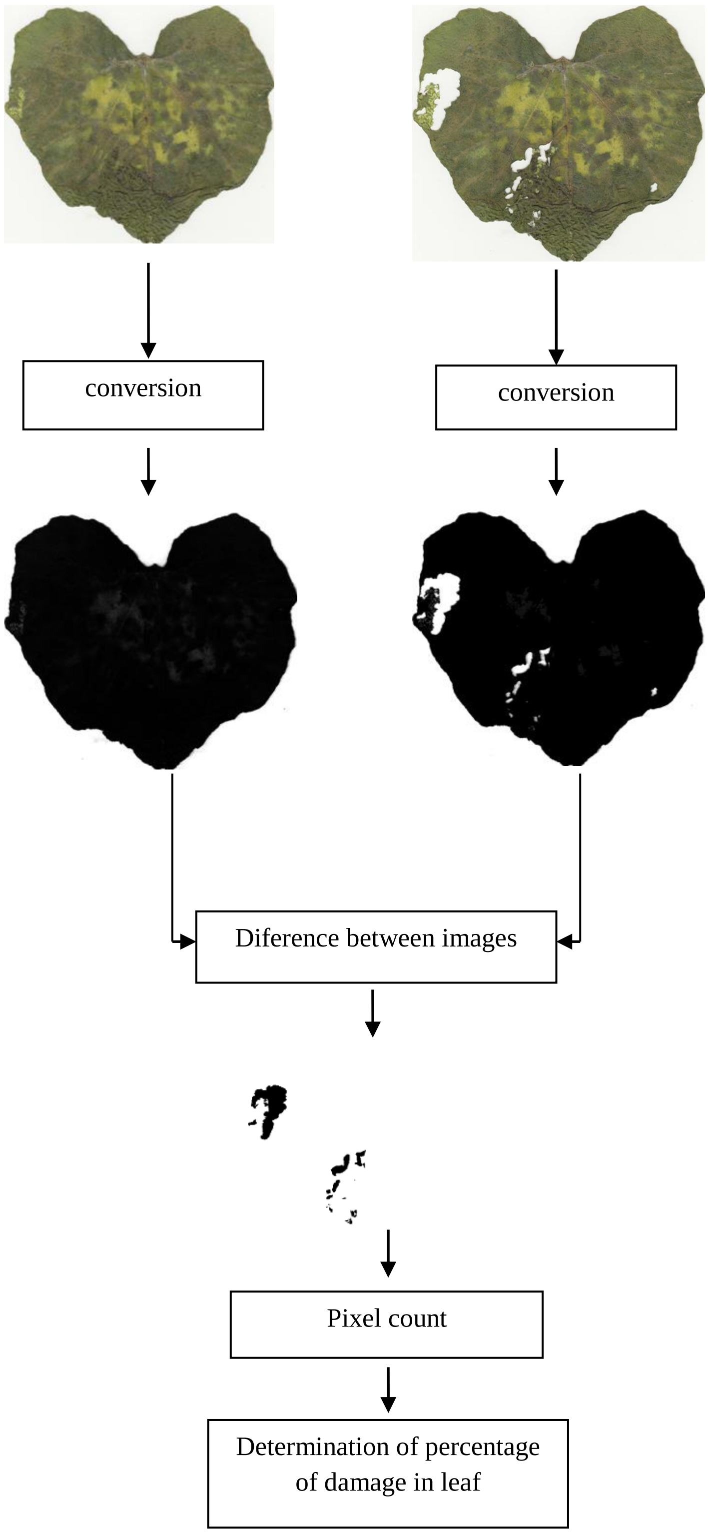


Figure 6. Flowchart for leaf damage determination

The program loads the files corresponding to the leaf when it has been just cut and when it has been already damaged then carries out the binarization using a threshold value 200. Next the area calculation is performed counting the pixels for each image. The difference between images corresponds to damage. The percentage of damage is obtained using equation 1:

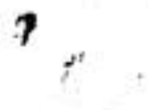
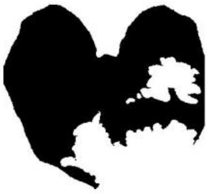
$$\frac{damagearea}{originalarea} * 100 \qquad (1)$$

Next, we are showing a simplified example of how the operations are performed:

Original image (scanned)						Damaged (scanned)						Damage surface (calculated)				
■	■	■	■	■					■	■		■	■	■		
	■	■	■		-			■	■		=		■			
		■	■					■	■							
		■						■								
Internal representation																
1	1	1	1	1		0	0	0	1	1		1	1	1	0	0
0	1	1	1	0	-	0	0	1	1	0	=	0	1	0	0	0
0	0	1	1	0		0	0	1	1	0		0	0	0	0	0
0	0	1	0	0		0	0	1	0	0		0	0	0	0	0

3. Results

To verify that the results provided by the program are accurate, a sample of known size (5 x 5 cm2) was scanned. Then a square of 2.5 x 2.5 was removed. Then (6.25 / 25) * 100 equals a quarter of the damaged area (25%).

Complete leaf	Damaged leaf	Damage area	% damaged area	Image size (pixels)	Execution time (seconds)
			2.77	316x360	0.72
			3.66	305x360	0.59
			30.2	317x315	2.04

4. Conclusions

Using computer vision techniques, a software tool has been developed that accurately responds to the requirement of measuring damaged leaf area.

The program has low computational cost. From the point of view of memory requirements, depends on the size of the images that are input for the analysis, whereas from the standpoint of computational time, it is observed a good performance.

The program has proved to be efficient and reliable and therefore, offer the possibility of designing inspection systems for the automatic measurement of foliage destroy by *D. hyalinata*. On the basis of digital image process algorithms, computer vision had the ability of reducing dependence on human graders increasing high quality throughput, reducing processing time and errors, improving results consistency and enhancing confidence in the safety and quality of such results. Thus, using the program will help establish guidelines for managing the population of *D. hyalinata*.

The result of the program is measured in pixels. From this result and calculating the relationship "pixel-image density" could be possible to transform the result to square centimeters or any other unit of measurement.

As a final note it must be remarked that we worked only with detached leaves and, as Benjamin, Freeman & Brown (1968) stated, "Techniques for estimating leaf areas vary greatly in instrumentation depending upon whether the leaves to be measured may be detached from the living plant and whether simplicity and rapidity of measurement are required" we are aware that the image capturing as well as the image segmentation stages will require further improvement to be useful in the crop fields.

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Development of an open source agricultural mobile data collector system

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A B S T R A C T

The information is important in every decision area. The Big Data philosophy lead to collect every possible data. Nowadays these applications are more and more successful in the following agricultural areas: different parts of food industry, extension services, precision agriculture. While studying the use of these new ICT technologies can be concluded that different types of services offer different possibilities. Firstly we compared the possible mainboards and sensors. General information about the existing mobile main boards. We compared the Atmel AVR, the Raspberry PI and the LEGO Mindstorms NXT. We choosed the Arduino system board. We described the main system architecture and connection possibilites. We found the temperature sensor widely useable. The software was also briefly mentioned. We can say there are several advantages of the Arduino. The whole system can be upgradeable, and there are several Arduino based mainboards and sensors too. Nowadays the block programming support are increasing (etc. MIT Appinventor), but there are disadvantages too. The system has several limitation: the number of the connected sensor, the connection type, the system energy supply, the data loss, the creation of user friendly interface and the system failure tolerability.

1. Introduction

The development of information technology has had a considerable influence on the agriculture. There have emerged a number of new industry-specific technologies and new applications over the past few years, including the ever widening agricultural application of mobile communications devices and technologies. Further considerable improvement is expected in the use of the mobile data collector devices.

The focus of our research was to develop mobile data collector device and the assessment of their effects on agriculture. Due to the fact that the development of applications and user applications require wide-ranging condition and effect the investigation of several conditions and effect mechanisms and research tasks were carried out.

Providing information: Management in agriculture is a large extent of the ability to make decisions under uncertainty, the latter being accumulated from three main sources (Thysen 2000)

- uncertainty due to lack of data about the current state of nature;
- uncertainty due to incomplete knowledge about the biological and physical systems and
- uncertainty due to inherently random processes.

The farmers' use of IT must be looked upon from the point of view of farm economics. The majority of farmers will only use IT if they consider this to be economically beneficial. There are, however, reasons to believe that the economical value of IT in farming is increasing, which eventually will lead to a higher uptake of the technology (Herdon & Lengyel, 2013). The main reason to expect a higher value of IT is the public concern about agriculture's negative impacts on the environment and the widespread fears concerning food safety. These consumer concerns are causing governments and primarily the food industry to enforce restrictions on the use of assumed harmful chemicals and,

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secondly, to demand a precise documentation of the primary production process (Herdon & Füzesi, 2011). ICT evolution is well advancing Moore's Law prediction of computer performance indexes. Indeed, these technologies are not only fast developed but, are giving birth to newer ones. These innovations of ICT are not only regenerating the agriculture (Sideridis et al., 2010).

The developments in wireless sensor technologies and classified the applications in agriculture and food production under several categories (Wang et al., 2006).They identified environmental monitoring (weather monitoring, geo referenced environmental monitoring) and precision agriculture (spatial data collection, precision irrigation) as the most spatially dependent. Environmental data are very important in agriculture, since crop yields depend on environmental conditions, and the response of plant growth to changing environmental conditions is extremely complicated (Lee et al., 2010).

We think that the importance of the big data is increasing in the field of agriculture. The idea of big data is not new but the current data analysis, data mining, data visualization simplify the farmers decision. Few possible fields of the sensor based big data are the following: yields, soils, weather analysis, crop models, market information, and complexity of them. The cloud based computing and mixture of the mobile sensor network are also a good combination.

2. Recent trends in mobile data collecting

2.1. Technology

Sensors are used for collecting information about physical and environmental attributes. There are several wireless sensors network application in agriculture (Aqell-ur-Rehman, et al., 2014). Agriculture information requirements could be the following:

1. Collection of weather, crop and soil information
2. Monitoring of distributed land
3. Multiple crops on single piece of land
4. Different fertilizer and water requirement to different pieces of uneven land
5. Diverse requirements of crops for different weather and soil conditions
6. Proactive solutions rather than reactive solutions.

Wireless communication technologies like ZigBee, Bluetooth, Wibree and WiFi are frequently used in Wireless Sensor Network (WSN). These technologies have different capabilities and properties on which they are complemented.

Wireless sensor node is a basic unit of wireless sensor network. It comprises of four basic modules including Sensor/Actuator module, Communication module, Processing/computation module and Power module. External memory is an optional module that could be needed in case of data storage requirement for local decision making (Aqeel-ur-Rehman, et al, 2014).

2.2. Typical agricultural data collector applications

There are several existing mobile application in the field of agricultural data collection. The real time soil near infrared sensor is proper tool for soil property mapping (Kodaira & Shibusawa, 2013). They mounted the mobile sensor on a tractor. They use halogen lamp to preserve the consistent light condition and the color values. For the general mobile data monitoring the ZigBee platform could be useful. These data also can be useable for artificial neural network application (Nadimi at al., 2012). The main conception was to create an animal welfare solution for sheep. The 2.4-GHz ZigBee-based mobile ad hoc wireless sensor network was reliable for communication. The mobile ad hoc wireless sensor network measured and monitored the behavioral parameters of each sheep in a herd. They classified the behavior of each individual animal into different modes (i.e. grazing, lying down, standing, walking and other modes). The sensor data visualization for agriculture has a great opportunity for mobile technology (Kubicek at al., 2013). For agriculture decision makers the Geographic Information System and the Wireless Sensor Networks (WSN) have a great opportunity. They suggested to use a following components for WSN:

- A heterogeneous distributed network of hierarchical agricultural sensors.
- Communication infrastructure and standardized interfaces between sensors and the Internet.
- Web-enabled geoinformation infrastructure for effective visualization of sensor data.
- Cartographic visualization rules and modeling tools for effective support of agricultural decision-making.
- An agricultural knowledge base and data warehouse for sensor data storing.

The wireless sensors also useable for irrigation water management (Stefanos et al, 2015; Navarro-Hellín et al., 2015). The GSM/GPRS protocol seem to be more flexible for data collection. The suggested subsystem are the following:

1. An electronic board, the Main-Board, this board is responsible for sensors' data and for the communication with the rest of the boards.
2. The Sensor-Board provides the interface with the connected sensors.
3. The GPRS-Board is in charge of establishing the communication with the mobile network by means of a GSM/GPRS protocol.

2.3. Agricultural application development

Studies of the situation of mobile communication and the new ICT technologies revealed that the international trends show the possibilities of these usage. The mobile devices indicate that both the interest and the potential volume of users are available in agriculture and every chance is there to exploit the opportunity of growth. As regards the devices themselves, they can be said to have increasingly more functions; a development which is ensured by the high level of integration. The earlier shown applications and innovative spread of the wired and the mobile Internet are primarily limited by economic and social factors.

3. The system development

3.1. Methodology

Firstly we did some research about the existing mobile data collector systems. The main idea was to develop an open source system architecture with cheap system parts. We collected information about the typical sensors. Secondly we created our system structure, then begun the programming. Thirdly after the first useable prototype we made practical data collecting experiment to check the system stability.

3.2. Technology

General information about the existing mobile main boards are the following.

Atmel AVR

The Atmel AVR is basically an 8 bit RISC microcontroller family (recently, the 32-bit version is also available), based on modified Harvard architecture. Some of these devices are on the market since 1996. Within the family we distinguish between 32 bit AVR UC3, 8 bit AVR XMEGA, mega AVR, tiny AVR types. These microcontrollers applied flash memory for the first time instead of the usual ROM, EPROM and EEPROM. In 2005, Arduino began selling its own development boards based on this microcontroller. Over the years more and more libraries have appeared, which made it possible to connect sensors and accessories to the system. This quickly made the developer motherboard popular for regular users as well.

Raspberry PI

The device is a very usable system, but it has another application area. It's more like a ready to use computer, rather than a development board. It has it's own operating system, which is also additional load to the device. With additional software we can experience unexpected problems during long-term running of the device. With a microcontroller there is no intermediate system, we have access to the full system functions, and in addition we can achieve satisfactory performance also with smaller hardware. The Raspberry PI is efficiently when used for computing-intensive operations, or graphical applications rather than control tasks.

LEGO Mindstorms NXT

This is a programmable robotics kit released by LEGO in late July 2006. It replaced the first-generation LEGO Mindstorms kit, which was called the Robotics Invention System. It comes with the NXT-G programming software, or optionally LabVIEW for LEGO MINDSTORMS. A variety of unofficial languages exist, such as NXC, NBC, leJOS NXJ, and RobotC. A new version of the set, the new Lego Mindstorms NXT 2.0, was released on August 1, 2009, featuring a color sensor and other upgraded capabilities. There is now a new Lego Mindstorms Robot, called the EV3. The main component in the kit is a brick-shaped computer called the NXT Intelligent Brick AKA(Ciara). It can take input from up to four sensors and control up to three motors. The brick has a 100×60 pixel monochrome LCD display and four buttons that can be used to navigate a user interface using hierarchical menus. It has a 32-bit Atmel microcontroller with 256KB of FLASH memory and 64KB of RAM, plus an 8-bit Atmel AVR ATmega48 microcontroller, and bluetooth support.

3.3. System architecture

The system structure can be separated into three main parts. The *sensor interface* is responsible for the connection of the sensors. The *controller* is responsible for the communication of the user interface and the data connection. The *user interface* allows the user to use the system. The main parts of the system can be seen in Figure 1.

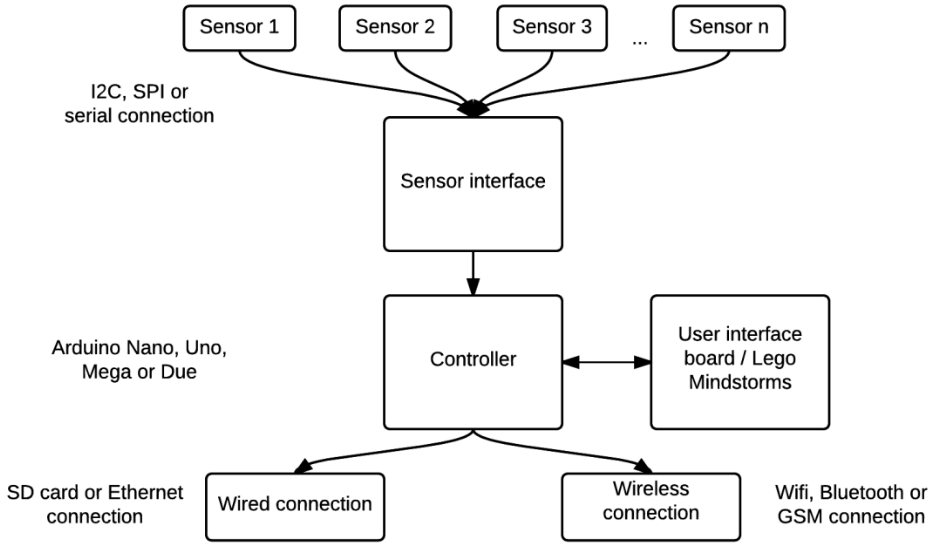

Figure 1. The main structure of the data collector system

Device control

The key component of a data collector device is the control unit, because it determines decisively the devices performance, expandability, and it sets the limits at the programs complexity. We will mention several systems later which can be used as opportunity, including the modular designed Lego Mindstorms system, which contains enough components for basic experiments, and the Arduino developer board, which gives us more customization possibility, but the use requires electronic design.

Control board

The motherboard as the name indicates, contains components, which gives basic functionality and power source. The Arduino provides this kind of motherboards based on Atmel microcontrollers, but we can also build one based on preliminary plans, as our concept describes it. The microcontroller used by the Arduino can be changed depending on the used functions, and the programs complexity.

The basic unit is an Atmel ATmega 328p microcontroller, which offers 32 Kbytes program memory, 13 digital and 5 analog inputs and outputs (with the support of I2C and SPI buses). It's considered as the simplest microcontroller what we used during the experiments. This microcontroller is used by the Arduino Uno developer board. The performance is good enough to perform more complex tasks, but the size of the memory is not sufficient to run the entire application what we made. The memory size cannot be changed because of the Harvard architecture, but a lot of microcontrollers also exists in the family, which may be suitable for this purpose.

Next opportunity is the Atmel ATmega 2560, which has much more memory compared to the previous one. With 256 Kbytes of program memory it is usable to make the whole system, and has approximately the same performance as the Uno. The power supply used by the devices is also seated on the motherboard. The module is quite simple, in case of using the ATmega 2560 or 328p because they have operating voltage of 5V. The maximum current provided by the device is 1.5A, which sufficient for the tasks, but aiming to reduce heat generation and provide enough power to the supplements may be used in the future is worth thinking about to equip the sensor board with an own power supply. The main data of the possible main boards can be seen in Table 1.

Table 1. The main data of the possible main boards

Type	**Clock speed**	**Flash memory**	**SRAM**	**Digital IO (PWM)**	**Analog Input**	**Arduino board**
Atmel ATmega328 (SMD)	16 Mhz	32 Kbyte	1 Kbyte	14 (6)	8	Arduino Nano
Atmel ATmega328 (DIP)	16 Mhz	32 Kbyte	2 Kbyte	14 (6)	6	Arduino Uno
Atmel Atmega2560	16 Mhz	256 Kbyte	8 Kbyte	54 (15)	16	Arduino Mega
Atmel AT91SAM3X8E	84 Mhz	512 Kbyte	96 Kbyte	54 (12)	12	Arduino Due

User interface

We can use more method to achieve the user interactivity. We designed a panel, which fits to the Arduino board as a shield. It contains 5 buttons for the navigation, from which is one equipped with interrupt capability. To set the value of the settings during the application we can use a matrix keyboard (with analog output) or a potentiometer, depending on the configuration. The former has the advantage that we have the opportunity to transmit exact values to the controller, but using it may result in more program inaccuracy because of the analog values. We used the matrix keyboard as an analog device, because with this method it reserves only one pin. We used a PCD8544 type 84x48 pixel monochrome display during the tests, which is connected via SPI bus of the microcontroller, however, in the case of development the size of the display, and the functions can greatly increase demands and the amount of information needs to be displayed.

One data collection method is can be performed with SD cards, also the interface is also can be found on this board. Similarly as the display, this component is also connected to the SPI bus, which slightly reduce the amount of wires between the controller and interface board. In addition to the SD card, we have the opportunity to use other wired (Ethernet controller) or wireless connections, like Wi-Fi communication, GSM and Bluetooth modules, XBee protocols. In addition to the aforementioned method we can use a properly programmed Lego Mindstorms NXT device to replace the interface board. In this case, the two devices communicating with each other using the I2C connection, which in terms of hierarchical sets the NXT as the master unit and the control board as slave.

Sensor boards

There was more concept born to design the sensor boards. The basic requirements are modularity, corresponding expandability and to minimize the need of user interaction to be done with an operation. To achieve this, the sensors or sensor panels must be identified to the system in some way. This method covers more options. Assume that there is the sensor panel, which contains more sensors inside of a printed circuit board. The panel has specific structure and connects to the motherboard based on a pre-designed interface with a 32-wire ribbon cable. With only one panel it would be easy, because we only have to write one program to make it function, but with more panels we have to achieve the identification as mentioned above. Information about few possible sensors can be seen in Table 2.

Table 2. The main data of the typical sensors

Type	**Application area**	**Accuracy**	**Interval**	**Interface**
DHT11	Temperature and humidity measurement	5% humidity and ±2 °C temperature	20-80% humidity and 0 to 50°C temperature	OneWire
BMP085	Barometric Pressure and temperature	±0.5 °C temperature ±0.2 hPa pressure	300 to 1100 hPa barometric pressure,	I2C
-	Soil moisture measurement	-	0 to 1023 (uncalibrated analog) or 0-1 (digital)	Analog or digital (logical)
MG-811	Carbon dioxide measurement	-	0 to 1023 (uncalibrated analog) or 0-1 (digital)	Analog or digital (logical)
TSL2561	Luminosity measurement	-	0.1 to 40000 Lux	I2C

Connecting the sensors can be done with simple digital, analog method, or with using I2C, and SPI bus system. Other concept describes the sensor board as a blank printed circuit, with sensor-specific interfaces, which act as a separated system, and the sensors can be replaced by the user (Table 3).

Table 3. The comparison of the possible wireless connection

Name	Frequency band	Range	Data rate	Cost	Modulation/ protocol	Security
ZigBee	2,4 Ghz	30m to 1.6Km	250 kbps	Low	DSSS, CSMA/CA	128 bit
Bluetooth	2,4 Ghz	9m to 90m	1 Mbps	Low	FHSS	64 or 128 bit
Wifi	2,4 Ghz	30m to 45m	11 to 54 Mbps	High	DSSS/CCK, OFDN	128 bit
GSM (GPRS)	GSM850MHz, GSM900MHz DCS1800MHz or PCS1900MHz	Depends on network	85.6 kbps	High	TCP/UDP, HTTP	128 bit

It would increase the usability, but in addition to it would increase the production cost, because we have to redesign all the used sensors in a specific way to make it compatible with the custom interface and useable with the identification system.

3.4. The software

When the software starts, it declares the global variables, and gives values from an EEPROM, to the variables contains the settings, which determines the system functions. The EEPROM is connected to the microcontroller via I2C bus, and the values contained by it are defined by a custom memory map. After the value assignment the software initializes the connected devices, in addition a basic debugging starts, which gives to the user feedback, when a sensor is malfunctioning during the launch.

The microcontroller are responsible for the sensor data read, the data are stored in global variables, so we can reach anywhere the measured data. During the experiments we used a 16x2 character matrix display, and an 84x48 pixel resolution graphic display. Depending on the configuration, it was able to show data from 6 sensors simultaneously, but this can be expanded with multiple pages.

After the display is done, the events are happening depending on the settings. If at the memory address 5 binary 1 value has been saved, the device tries to perform data saving to the SD card. If there is an issue with the card, or cannot be detected in the system, an error message is generated to warn the user. With operating card, the device creates a directory structure, and the data collection begins to a .txt file using defined file structure. This structure facilitates the subsequent processing.

The next step is data collection using the Ethernet connection. The binary value at memory address 8 activates this function. In this case the device uploads the measured values to a pre-structured SQL database automatically. There is SQL library specifically for this purpose which can be used, but the library uses large amounts of memory. This resource usage is noticeable during the usage. Another option works with a PHP website. We use this site as a data processor, which takes the value from the system as a String and properly transfers it to the database.

We had experiment related to data analysis, but in other application area. The Ethernet connection can be replaced by WiFi or GSM based data transmission as well. These two methods is probably much more practical, since they are wireless communications, but due to lack of equipment, we have focused to the Ethernet.

3.5. Testing results

The application based on the system are tested on every module. With this method we can achieve easier debug opportunity and optimized program. The first step was to read the sensors, the conversion of the measured data, then to send them to the serial monitor. It was necessary to test the proper connection and functionality of the sensors. The connection is usually clear, but hardware conflicts should be corrected. Since this has worked successfully, the data should be visible to the user. We used a 16x2 character matrix display and a 84x48 pixel graphic display. At this stage we have not used the menu system, but assuming the future development, we created the function when we first time used the display. The sensors and the display worked properly, so it was necessary to develop the data collection methods. The first, and also the easiest solution was to collect data to an SD card. Due to the complexity of the system, the actual limitations are the following: the optimization of the battery time is still an issue, the compact and weather resistant case is not completed yet, the sensor calibration is depends on the actual usage type, the user interface is only in a beginning state.

We did not make a data analysis because of the prototype device, when we calibrate all the sensors and finalize the control board we will make the collected data evaluation.

The results show the base system is applicable and the structure can be upgradeable. The full system durability test are the next step and after it we can say the final verdict about it. We hope it will be capable to achieve more results.

3. Conclusion

After the development phases we can say there are several advantages of the Arduino. First of all the whole system can be upgradeable, and there are several mainboards and sensors too. Secondly the software support is great. Also there are good possibilities in block programming (predefined program modules). The block programming support are increasing (etc. MIT Appinventor). Of course there are disadvantages too. The system has several limitation: the number of the connected sensor, the connection, the system energy supply, the data loss, the creation of user friendly interface and the system failure tolerability. As regards the devices themselves, they can be said to have increasingly more functions; a development which is ensured by the high level of integration. Finally we can say both the main board technology and the potential sensors are available in agriculture data collection.

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Attitude of crop farmers towards e-wallet platform of the Growth Enhancement Support Scheme for input delivery in Oke-Ogun area of Oyo state

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ABSTRACT

E-wallet-powered Growth Enhancement Support Scheme was designed by the Nigerian Government to facilitate and improve farmers' prompt access to agricultural information and input services. An assessment of the pilot phase of the scheme becomes necessary for an effective implementation. The study therefore assessed the attitude of crop farmers towards the e-wallet platform of the Growth Enhancement Support Scheme. A total of 120 crop farmers across the study area were sampled through a simple random sampling method. Data were collected through a well-structured interview schedule, and analysed using percentages, PPMC and Chi-square. Farmers' mean age was 47 years. Majority were males, married and have an average of 15 years farming experience. Maize and cassava were the most grown crops. Majority indicated non commitment of the ADP and long distance to redemption centre as major constraints to use of e-wallet. More than half had favourable attitude towards the e-wallet platform of the Scheme. There is significant relationship between the years of farming and educational level with farmers' attitude towards the e-wallet. Constraints faced also had negative influence on attitude to the scheme. Establishment of more redemption centres to stop the rigor of long queues and reduce long distance covered before accessing the centres will make prompt access to information targeted by e-wallet achieve desired end.

1. Introduction

In many developing countries, efforts at agricultural progress have failed because of inadequate attention to one or more components of successful policy (Jagdish 1996). That has over the years reduced agriculture revenue generation. Pulitzer (2012) reported that in Nigeria, Africa's most populous country, a legacy of sharp practices and an economy based primarily on oil exports has left the agricultural sector significantly weakened and millions of Nigerians hungry. Adeshina (2013) also posited that Nigeria's development efforts have over the years been characterized by lack of continuity, consistency and commitment to agreed policies, programs and projects as well as an absence of a long-term perspective. The culminating effect has been growth and development of the Nigerian economy without a concomitant improvement in agricultural system in Nigeria.

Ogundari and Ojo (2007) in Adebo (2014) equally observed that despite various efforts geared towards agricultural development, it has been estimated that 65% of Nigerians are living with hunger as food production growth is still as low as 2.5% per annum, while food demand have been growing at the rate of 2.8% per annum. There is high incidence of poverty among participants in agriculture, who are mostly rural based. In relation with GDP, the share of the agricultural sector has been less than 45% since 1986 (CBN, 2003). Another factor contributing to this discouraging trend is the fact that agriculture in Nigeria is dominated by small scale farmers, who, in addition to low level of education, maintain low level of contact with extension services, low input, and poor advisory service. Policy inconsistencies and too much emphasis on production without due consideration to other value chain

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requirement have been identified as often responsible for the worsening scenarios. Corroborating this, Idachaba (2013) also posited that the dismal performance of the agricultural sub-sector in Nigeria is largely due to a number of factors among which are corruption and policy summersault. For instance, it was documented that between 1977 and 1996, the Federal Government implemented an annual programme of fertilizer procurement and distribution nationwide. In 1997, the fertilizer sub-sector was abruptly liberalized without a proper transition plan in place to encourage the organized private sector fill the gap left by government (FMAWR&D, 2000). Fertilizer application then went down from a peak of 1.2 million tons in 1992 to a paltry 56,706 metric tons in 1997. Two years later; in 1999, subsidy was again re-introduced at a level of 25% and continued till year 2010 under the Fertilizer Market Stabilization Programme (FMSP). However, there were evidences that only 11 % of the subsidized fertilizer actually reached the small holder farmers for which it was intended (FMARD, 2012).

The need for a holistic transformation of the Nigerian State has necessitated a strategy that gives cognizance to Growth Enhancement Support Scheme (GESS). The scheme was introduced in May 2012, as a pilot project in 36 states and the Federal Capital Territory. Being powered by the e-wallet approach, the scheme aims at achieving the set goals of overcoming the many difficulties confronting the agricultural sector in Nigeria and ensuring availability of fertiliser, seeds and other inputs to farmers as timely as possible. This is with the understanding that the corruption which has been the bane of agricultural development in Nigeria will be better tackled if and when farmers can directly access the government through their mobile phones. An e-wallet has thus been defined as an efficient and transparent electronic device system that makes use of vouchers for the purchase and distribution of agricultural inputs (Ezeh, 2013, Adesina, 2013).

The e-wallet approach is designed for smallholder farmers, who appear the most hit and vulnerable by the impropriety in the fertilizer and other input sector of the Agriculture Ministry. The criteria for farmer's participation include: farmers being above 18 years old; have participated in a survey authorized by the government to capture farmers personal detailed information; must own a cell phone with a registered SIM card and have at least sixty naira credit in the cell phone. The fulfilment of these conditions guarantees the issuance of an e-wallet voucher to the farmer. The voucher is used to redeem fertilizers, seeds and other agricultural inputs from agro-dealers at half the cost (Signal Alliance, 2014). Adebo (2014) further highlighted that for an agro input dealer to participate in the programme, he/she must own a cell phone with a registered SIM card, understand the process of using e-wallets, and attend training programmes designed for the project. The agro dealers are required to conduct honest business and guide against fraud; choose and prepare a location for the business transaction; provide storage facilities and be available at the appropriate time to attend to farmers' needs. Other prominent personalities in the scheme are the helpline personnel and redemption supervisors. Each state Agricultural Development Project (ADP) supplied the helpline staffs, and about 3-5 helpline staffs are assigned to each of the Local Government Area. The helpline staff and supervisors connect to the farmers on a daily basis to attend to their needs. The redemption supervisor helps in verifying farmer's identity as well as a farmer's code in the text message received by the farmer, and then compares it with the name and code listed in the farmers register which the supervisor received from the cellular. The subsidized farm inputs are delivered directly to farmers through their mobile phones. The project is expected to provide direct linkage between the farmers and the government. This will enable the government to disseminate valuable information to the farmers, thus ensuring farmers' progress (Ezeh, 2013). The system ensures the involvement of the private sector in agricultural input supply (NAN, 2012). According to the Federal Ministry of Agriculture and Rural Development (2011), about 14 million farmers have registered for the scheme throughout the federation. Inputs have been distributed in along seasonal production cycles to farmers for their needs and interest, for which the programme have been designed primarily.

Achieving the set goals of the GESS however requires having inputs in the form of a feedback from the primary beneficiary (farmers) on the pilot phase recently concluded before full implementation ensues. This is because sustainability of any programme and the success of similar programmes in the future cannot be divorced from the attitudinal disposition of the target beneficiaries. It is equally important to ascertain how the use of ICTs in the form of e-wallet as introduced by the federal ministry of Agriculture can be an effective tool in transforming the national agriculture, which has been anchored by the Agricultural transformation Agenda (ATA) of the federal government. It is against this background that this study has been designed to access the attitude of crop farmers towards the e-wallet platform of the GESS for input delivery in Oke-Ogun area of Oyo state.

The following specific objectives were achieved in the study: to

1. To identify the constraints to use of the e-wallet platform of the GESS
2. To ascertain farmers' attitude to e-wallet components of the GESS in the study area.

The following research hypotheses stated were also tested.

Ho1: There is no significant relationship between the farmers' socio economic characteristics and their attitude towards the use of e-wallet for accessing agricultural inputs.

Ho2: There is no significant relationship between respondents' constraints faced and their attitudes to the use of e-wallet for accessing agricultural inputs.

2. Methodology

The study was carried out in Oke-Ogun area of Oyo State. The area is located within the Guinea Savannah Zone. It shares border with Kwara, Niger, Ogun and Osun states, as well as Niger Republic (a neighbouring country). The area is recognized as the 'food basket' of the Southwestern Nigeria, having an annual rainfall ranging between 700-1100mm. The landmass of Oke-Ogun is about 13,537 Sq. Km. This is about 60% of the total land mass of the present Oyo State. The people are Yorubas and the main economic activities include: farming, hunting, fishing, food processing, transportation and craft businesses. Most farm families reside in the various settlements abounding in the villages and farmers still adopt traditional cultivation methods. Although there is a limited level of infrastructural and institutional development in the study area, GSM services is wide-spread across the entire area mainly provided by the MTN, Globacom, Etisalat and Airtel GSM companies. The common food crops grown in the area include yam, cassava, maize, vegetables, melon, guinea corn, pawpaw, water melon, plantain, banana, orange, mango, cashew cowpea and groundnut. Farmers still make use of traditional tools such as cutlass, hoe, axe, and so on.

A multistage sampling procedure was used to select respondents for this study. There are ten local government areas in the study area. Five LGAs were randomly selected (Atisbo, Iseyin, Itesiwaju, Iwajowa, Irepo) representing 50% of the Oke-ogun area. A representative 50% was considered good enough since the all the ten LGAs in the study area share the same characteristics in terms of Agricultural Extension Programme (ADP) structure in the state. Sangotegbe et al. (2012) sampled 20% of the LGA in a study carried out in the same area. A list of all farmers registered with the ADP was obtained for each LGA and 10% of the farmers on this list was randomly sampled and selected for the study, giving a total of 120 sampled farmers. However, only 118 research instruments were used for analysis as two were not properly filled giving a return rate of 98.3%. The population of study comprised of all crop farmers, and data were obtained with the aid of a well-structured interview schedule.

Attitude to the e-wallet platform was measured by presenting respondents with a list of statements that bother on the e-wallet platform of the GESS. This was measured on a 5-point rating scale, of strongly agree (SA), agree (A), undecided (U), disagree (D) and strongly disagree (SD). Scores of 5, 4, 3, 2, and 1 were awarded to positive statements from strongly disagree respectively and the reverse for negative statements. Mean score was computed from the respondents' attitudinal scores, and used as a benchmark for categorising respondents into having favourable and unfavourable attitudes. Respondents reacted to the listed constraints on a three-point scale of severe constraint, Mild constraint and not a constraint. Scores of 0, 1 and 2 were assigned respectively. The mean score for each constraint was calculated and was used to rank them in order of severity.

Reliability of the research instrument was carried out as the scale developed for each variable was presented to experts in the field of Agricultural Extension and Rural Development, University of Ibadan, Nigeria for content and construct validity. A total of 30 pre-test instruments were administered on 20 respondents, in Ido local Government area of Oyo state. Using the statistical package for Social Science (SPSS), version 16, a reliability analysis was carried out. Split-half method was used for data analysis and r = 0.75 implied the instrument was reliable, after which the instrument was multiplied for the main data collection. Interview schedule was manually administered on all respondents for the study. Data analysis was carried out with the use of SPSS Version 16, Microsoft Excel (2010). Mean, frequency counts and percentages were used to describe the data by SPSS, while the Microsoft Excel (2010) was used to draw bar chat (Figure 1). The hypotheses were also tested with the use of Chi-square and Pearson Product Moment Correlation, using the SPSS.

3. Results and discussion

Socio-economic characteristics of respondents

Table 1 shows that 26.3% were within the age bracket of 41-50 years, while 24.6% were within the age bracket of 51-60. This implies that majority (83.9%) of the respondents were in their active age (20-59) and this is in line with the work of Akinbile and Odebode (2002) which states that the population within the age group of 16-55 years constitute the active workforce in Nigeria. Furthermore, it can be inferred from Table 1. that the population of youths is low as only 11% of the respondents were within this range; Rural-urban migration is prevalent within this age range as most of the youths move to urban areas in search of better livelihood. This could mean loss of labour for agricultural activities in rural areas.

Table 1 further reveals that 68.6% were male, while 31.4% of the respondents were female. This implies that male participation in agricultural production in the study area is more pronounced than that of female. Also, 75.4% were married. This further confirms the existence of strong family/marriage ties among rural dwellers. According to Akinbile (2007), that marriage confers responsibility, there is the need to increase their productivity levels by improving their access to inputs, through such platforms like the e-wallet.

Findings further shows (Table 1.) that 34.7% of the respondents attended secondary school, while 32.2% had primary school education and 24.6% were graduates of tertiary institutions. The basic objective of any form of education is to impact knowledge which would influence a change in attitude, skills, or knowledge. It therefore implies that crop farmers in the study area will not have much problems making use of the e-wallet platform for accessing inputs for improved agricultural productivity in the study area.

As shown in the Table 1 73.7% of the respondents had 2-5% hectares of farmland, while 22.9% had less than 1 hectare, and 2.5% had up to 6-9 hectares. This establishes the fact that, Nigeria farmers are small scaled Such intervention as the e-wallet is necessary, as it can help improve the status of the farmers in the area, guaranteeing timely access to fertilizer, seeds and other essential agricultural inputs.

Table 1. Distribution of respondents by personal characteristics

Personal Characteristics	Frequency (f)	%	Mean
Age (Years)			**47**
21 – 30	13	11.0	
31 – 40	26	22.0	
41 – 50	31	26.3	
51- 60	29	24.6	
60 Above	19	16.1	
Sex			
Male	81	68.6	
Female	37	31.4	
Marital Status			
Single	11	9.3	
Married	89	75.4	
Widowed	12	10.2	
Divorced	6	5.1	
Educational			
Primary	38	32.2	
Secondary	41	34.7	

Tertiary	29	24.6	
Others	10	8.5	
Years of Farming			**15**
Less than 10yrs	47	39.8	
11-20	42	35.6	
21-30	21	17.8	
31-40	6	5.1	
Greater than 41	2	1.7	
Size Of farm land cultivated			**3**
Less or equal to 1	27	22.9	
2-5	87	73.7	
6-9	3	2.5	
Major crop 1			
Maize	52	44.1	
Cassava	26	22.0	
Vegetable	8	6.8	
Water melon	5	4.2	
Vegetable	7	5.9	
Others	20	14.3	

Source: Field Survey, 2013

Figure 1 shows the various crops cultivated by the respondents in the study area. The study reveals that crop farmers in Oke-Ogun area of Oyo state were predominantly into food crop production. The study reveals that of the major crops indicated by the respondents, maize was the most prominently (44.1%) grown in the study area, followed by cassava (22.0%). This suggests that the climatic and soil condition of Oke-Ogun, favour most the cultivation of maize and cassava. This further revalidates the fact that Oke-Ogun is the food basket of Oyo state as posited by Sangotegbe et al., (2012). This is because maize and cassava form the main food component in many households in the Oyo state.

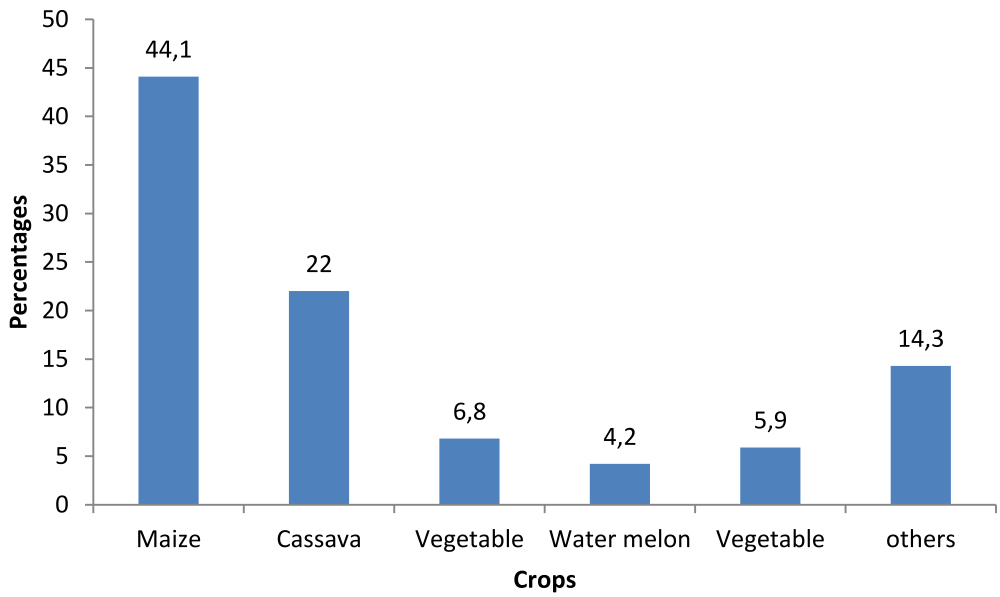

Figure 1. Distribution or respondents based on major crops grown

Source: Field Survey, 2013

Constraints to use of the e-wallet-powered GESS

GESS, through the e-wallet platform is not without associated challenges. The study (Table 2) identified the various constraints to the e-wallet powered GESS in the study area. Findings reveal that majority (66.9%) of the respondents indicated non commitment of the ADP was a major constraint of the scheme, while 38.1% believed that, the distance covered from their home to the redemption office was too long. Also, the findings reveal that some (28.8%) of the respondents claimed that the interference in the operation by influential people is a hindrance to the success of the scheme. From the table, it can be inferred, that all other constraints facing the scheme which included long queues at the redemption centres, coming late of mobile alert, sharp practices and long distances covered from home to redemption stations are traceable to either non-commitment of the ADP or low extension agents-farmer ratio, or both. These findings partly agree with Adebo (2014), who identified similar constraints to the implementation of GESS. Osinowo (2012) also identified institutional, political, managerial, economic and social issues as the serious challenges and constraints facing the sustainability of the Agricultural Transformation Agenda and the GESS of the Federal Republic of Nigeria.

Table 2. Constraints to the use of e-wallet platform of the GESS

Statements	Not a constraint	Mild constraint	Severe constraint
Stress farmers go through in order to get inputs	22.9	54.2	22.0
Long queues at the redemption centers	19.5	63.6	16.9
High transaction cost incurred by farmers	37.3	58.5	4.2
Sharp practice by input distributors/dealers	36.4	48.3	15.3
Late supply of inputs	15.3	56.8	28.0
Long distance covered from home to redemption	19.5	42.4	38.1
Interference in operation by govt agent/officials	31.4	37.3	31.4
Mobile alert message come late	34.7	50.0	15.3
Non commitment of ADP staff of GESS	12.7	20.3	66.9
Less quantity of agro-inputs allocation	16.9	50.0	33.1
Agro-inputs supplied are not suitable for production	56.8	28.8	14.4
Interference in the operation by influential people	16.1	55.1	28.8

Source: Field Survey, 2013

Attitudes of crop farmers towards the e-wallet platform of the GESS

The study (Table 3) reveals that 50.0% and 61.0% respectively of respondents strongly agreed that telephone method is very suitable to access input for farmers and that e-wallet will blossom more with more commitment from ADP staff and. Also, almost half of respondents strongly agreed that the *modus* operandi of e-wallet is suitable for the rural farmer (48.5%) and that e-wallet has instilled farmers' interest in further agricultural programmes (49.2%). This implies that crop farmers have good attitudinal disposition towards the Scheme in the study area. The study further reveals that a sizeable number of respondents agreed that GESS's e-wallet platform has reduced corruption in input supply (58.5%). This implies that e-wallet platform has been able to address the problems of corruption in the supply of agricultural inputs, and thereby achieving one of the main aims for which the scheme was launched. The findings further reveal that majority of farmers agreed that success would be achieved in developing agriculture, if e-wallet is sustained. This is another pointer to the fact that the e-wallet platform has been able to address farmers' needs properly that they now have some levels of trust and confidence in government agricultural programmes. This has a lot of far-reaching effects on sustained food availability, and in no time, the issue of food insecurity would have been reduced to the barest minimum. The study reveals that a sizeable number (50.0%) agreed that more farmers will emerge if GESS's e-wallet implementation is extended

Also, the study reveals that majority (58.5%) disagreed that –the e-wallet platform has not really eliminated intrusion of supplied agro-inputs by different dealers and that the scheme is only beneficial to selected group of farmers because they are influential (47.5%), and 39.0% that although GESS is beneficial, it has wasted a lot of resources that outweighed the gains. The findings are pointers to the fact that majority of the farmers have favourable attitude to the programme in the study area. This suggests that the scheme will fulfil the various promises and prospects accruable, when the full implementation finally ensues. Tiri et al., (2014) had highlighted the prospects, positing that the scheme will serve as a stimulus for modern economy and enhance rural income. If this policy frame work is well pursued, it will also reduce Nigeria food import bill and stimulate agricultural export. Indeed it will stimulate the growth of the agricultural sector and by extension, the economy.

Table 3. Distribution of respondents based on their attitudes to the e-wallet platform of the GESS

Statements	SA	A	U	D	SD
e-wallet platform will end up in failure as past programme	67.8	27.1	1.7	0.8	2.5
Telephone method is very suitable to access input for farmers	50.0	44.9	3.4	1.7	0.0
GESS's e-wallet platform has reduced corruption in input supply	34.7	58.5	6.8	0.0	0.0
The *modus* operandi of e-wallet is suitable for the rural farmer	48.5	46.6	4.2	0.8	2.5
Success would be achieve in developing agriculture if e-wallet is sustained	30.5	68.5	6.8	3.4	0.8
Benefits derived from the GESS's e-wallet is not worth time invested in it	22.9	24.6	5.1	30.5	16.9
e-wallet adequately address farmer's inputs needs, without much stress	16.9	2.0	26.3	26.3	8.5
Agro-input distribution timing is appropriate with e-wallet	24.6	31.4	16.9	18.6	8.5
GESS could have been better if farmers were consulted	33.1	43.2	8.5	9.3	9.5
Poor feedback opportunity makes the e-wallet platform uninteresting to me.	23.7	33.9	20.3	15.3	6.8
E-wallet has instilled farmers' interest in further agricultural programmes.	49.2	37.3	4.2	5.9	3.4
GESS is though beneficial, but has wasted a lot of resources that outweighed the gains.	19.5	8.5	1.7	39.0	31.4
E-wallet will blossom more with more commitment from ADP staff and Cellulants.	61.0	28.0	6.8	1.7	2.5
More farmers will emerge if GESS's e-wallet implementation is extended	41.5	50.0	4.2	3.4	0.8
General neglect of farmers perception is a major impediment for a successful e-wallet scheme	28.0	35.6	23.7	8.5	4.2
All services provided by e-wallet platform are beneficial to all individual farmers	18.6	23.7	16.9	33.9	6.8
E-wallet platform has not really eliminated intrusion of supplied agro-inputs by different leaders	16.1	8.5	12.7	58.5	4.2
The scheme is only beneficial to selected group of farmers because they are influential	17.8	8.5	4.2	47.5	22.0
The e-wallet has achieved only so small than the general expectation from the government	3.4	6.8	44.1	44.9	0.8
The too many success noise about e-wallet is truly nothing but propaganda.	12.7	10.2	9.3	60.2	7.6

SA = Strongly Agree, A = Agree = A, (U = undecided, D = Disagree and SD = Strongly Disagree

Source: Field Survey, 2013

The overall attitude of the farmers was represented in two categories of favourable and unfavourable (Table 4). This was determined as the mean attitude scores was computed and used as the benchmark, such that respondents whose scores are below the mean attitude scores were categorised in 'unfavourable', while those whose scores are equal or greater than the mean were categorised in' favourable'. Table 4 indicates that 56.8% of the respondents showed favourable attitude towards e-wallet platform, while only 43.2% had unfavourable attitude. This shows that majority of the respondent have favourable attitude towards the e-wallet platform of the GESS scheme. Favourable attitude of farmers towards GESS allows them have access to improved agricultural input as offered by the scheme. This is expected to bring immediate benefits to farmers in terms of improved productivity and food security, while it also helps improve agriculture, food security situation and national economy.

Table 3. Respondents' overall attitudes towards the e-wallet platform of the Growth Enhancement Support Scheme (GESS) for accessing inputs

Attitude	Score	f	%
Favourable	64-74	67	56.8
Unfavourable	51-63	51	43.2

Source: Field Survey, 2013

Test of hypotheses

Hypothesis 1: There is no significant relationship between the respondent's socio economic characteristics and their attitude towards the e-wallet platform of the GESS.

Table 5 shows that there is significant relationship between the years of farming of the sampled respondents and their attitude towards the e-wallet platform of the GESS. Likewise there is a significant relationship between respondents' education and their attitude towards the GESS. However there is no significant relationship between respondents' age, size of farm land and their attitude towards GESS. This is against the findings of Ogunsumi (2011) whereas age and farm size showed significant relationship with farmers' adoption behaviour towards improved agricultural practices. It however agrees with the findings of Igodan et al., (1997) and Angba (2000), which revealed that increasing farm size does not necessarily result in positive adoption behaviour.

Table 5. Chi – square analysis of farmers' personal characteristics and attitude the e-wallet platform

Variables	df	-value	p- value	Decision
Age	4	1.544	0.819	Not significant
Years of farming	4	*11.278	0.024	Significant
Size of farmland	3	1.945	0.584	Not significant
Marital status	3	5.987	0.112	Not significant
Religion	2	1.602	0.449	Not significant
Education	3	*10.876	0.012	Significant

Source: Field Survey, 2013

Hypothesis 2: There is no significant correlation between constraints and attitudes towards the e-wallet platform of the GESS.

Table 6 shows that there was significant correlation between respondent's constraints and their attitude towards the GESS. The implication is that constraints faced by respondents play a significant role in influencing the attitude of farmers towards the e-wallet platform of the GESS. This agrees with the findings of Nweke et al., (2002) and Teklewold et al., (2006) that there are constraints to adoption of agricultural innovations in rural farming communities. In some instances, farmers reject some of the development programmes due to cultural background and inhibitions due to past bureaucracy faced and elite capture of previous schemes.

Table 6. PPMC analysis of farmers' constraints, awareness and attitude towards GESS

Variables	N	r - value	p – value	Decision
Constraints	118	-0.303	0.001*	Significant

Source: Field Survey, 2013

4. Conclusion and recommendations

The government over time had invested into agricultural promotional programme and agricultural support scheme leading to development and dissemination of various policies to improve agricultural production, consequently leading to food security of the nation. The success or otherwise of such programmes are often dependent on the behaviour of the farming population towards them. Findings from this study have shown that majority of the respondent have favourable attitude towards the e-wallet platform of the GESS. This is expected to translate into improved adoption of agricultural technologies and productivity of crop farmers in Oke-Ogun area, renowned for intense food production in south western Nigeria. This is in spite of the constraints faced by the as revealed by the study. From the findings of the study, the following recommendations are necessary for a more sustainable GESS and similar future programmes.

1. Government should support in promoting GESS by recruiting more ADP workers and reinforcing the existing ones so as to ensure adequate contact with the farmers, as this will facilitate prompt redemption of agricultural inputs.
2. The agencies involved in the GESS should ensure that only good quality fertilizer and other agricultural inputs are made available to the farmers, as this will not only help win the trust of the farmers on government programmes, but will also help guarantee optimal agricultural productivity.
3. Establishment of more redemption centre to stop the rigor of long queue and reduce long distance covered before accessing the centre should be ensured.

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Gender Analysis of Agricultural Innovation and Decision Making among Rice Farming Household in Nigeria

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ABSTRACT

Rice importance in food security and contribution to Nigeria economy cannot be overlooked, rice is produced in Nigeria but productivity increase has been a challenge due to many factors. Actors involved in the production process include women who are faced with formidable obstacles. This research analyze agricultural innovation, constraints faced by male and female rice farming households and decision making among rice farming household in Nigeria rice hub. A 3-stage stratified random sampling procedure were used, descriptive statistics, Ordinal Ranking, Least Significant Difference and Women empowerment index were the tool of analysis. The study showed that 23.81% of the respondents are female-headed and 76.19% are male-headed; more than half of the women (54.29%) are without formal education as compared to men (25.89%). Only 13.39% and 8.57% of the male and female headed household use rice innovation; access to credit, high cost of input and poor soil fertility are the major constraints; women empowerment results showed 76.60% of decision is made by solely by male head, 7.80% is made by female and 7.09% of decisions are jointly made. The study recommends that; innovation usage should be advocated, subsidy should be intensified and gender consideration in decision making be made a priority.

1. Introduction

Nigeria is the most populous country in Africa, with a population of about 168 million people. Its domestic economy is dominated by agriculture, which accounts for about 40% of the Gross Domestic Product (GDP) and two-thirds of the labour force. Agriculture supplies food, raw materials and generates household income for the majority of the people (Federal Office of Statistics, 2012). Over the years, improvement in agricultural production has led to specializing in certain crops or products; maize, cowpea, sorghum, rice, etc. (Plucknett et al., 2000). Rice has emerged as one of the fastest growing agricultural sub-sector, it has moved from a ceremonial to a staple food in many homes, such that some families cannot do without rice in a day. (Idiong et al., 2006). Rice is produced in Nigeria using a variety of rice production systems and technological levels coexisting together, the production involve a chain of activities ranging from land clearing to post harvest activities such as winnowing,

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threshing among others which is been done by male and female small holder farmers who use traditional manual methods that are characterized with problems of low productivity and consequently poor livelihood (World Bank, 2013). Increase in production has been achieved largely through extending the area under cultivation rather than using productivity-improving technologies (FAO, 1999). Within this production cycle, women have been reported playing vital roles in rice production, processing and marketing.(Rahman 2004) However, women have limited access to a wide range of physical assets including agricultural inputs, technological resources, land, and so forth (Arndt & Tarp, 2000). Women are a key part of the mainstream in agriculture, yet they face formidable obstacles (Kandiwa, 2013). Ayinde et al. (2013a) opined that, it is of importance to have strategy to put men and women's concerns and experiences at the centre of research design, implementation, monitoring, and evaluation. This involves looking at the socioeconomic settings of men and women to ensure that they benefit equally – often referred to as "gender mainstreaming". Bridging the gap in access to technology between men and women, we could increase productivity; Ayinde et.al. (2013b) further affirmed that technological adoption among male and female farmers is crucial to improving the productivity in the face of climate change. Transformation lies in using innovation to improve the products and services delivered by men and women who are actors in rice production. However, the prevailing condition in Nigeria is characterized with gender blindness, deafness and dumbness in the formulation and implementation of most rice productivity policies (Ajani, 2008). Despite the effort to intensify increase in rice productivity, the demand for rice has been on the increase in the country and sadly Nigeria has not been able to produce enough rice for the domestic need of her teaming increasing population. Recognition of gender disaggregated constraints, gender imbalances, differentials in gender roles and decision making as related to rice production, technological transfer; input used, method of farming, processing is important for any transformation of Nigeria rice sector. It is against this background the study to answer the following; what are the socio-economic characteristics of male and female headed rice farming household in the study area? What are the available rice innovations? and the level of women participation in decision making within the rice farming households which has not been carried out in this rice hub before now.

2. Theoretical Framework

This study is based on the theory of production, which states that, given level of technology and production inputs, an efficient producer will achieve maximum production of outputs. This theory assumed effects of external and internal factors on different households (especially smallholder farmers) in agricultural production (Quisumbing, 1996). A production function is a technical relationship between inputs and outputs that specifies the maximum level of output possible, given input levels. The production function shows the ability of a farm manager to critically consider available production resources, make necessary decisions and produce output, given level of technology (Auma, 2010).

As a general preposition; provided technologies and managerial decision making skills are the same, farmers who have identical access to identical factors (both quantity and quality) may produce identical outputs of a given crop which will have overall effect on their income and subsequent poverty status within the economic society. That is, their productivity will be identical. If they use different technologies, or different quantities of these factors, or there is difference in quality of these factors, their productivity will differ. There may be differences in the productivity of male and female farmers and their income will drop which may also make them sit among the vast majority of the poor. Men and women within the rural African household pursue both on farm and off-farm activities and have different endowments such as land rights and education, and different access to technologies, to factors of production such as labour and capital, and to support services such as extension and credit and their level of decision making differs on productive inputs and other household activities. Such factors affect households engaged in agricultural production differently. Gender of the household head (farm manager) is an internal factor that may hinder achievement of efficiency in agricultural production amongst the smallholder farmers due to decision making ability. Gender is the cultural interpretation of sex which considers socially constructed roles, responsibilities, characteristics, attitudes, and beliefs towards men and women. These roles are defined, supported, and reinforced by societal structures and institutions.

There are two approaches to production function, the primal (direct estimation of production function) and dual approach (indirect estimation of production function through profit or cost function). Most studies on analysis of gender effects on agricultural productivity used primal approach to production function and the application of dual approach is quite recent (Quisumbing, 1995). Primal-approach to production function analyzes and estimates directly the production functions of a farm manager (gender of household head) i in household j

$Y_{ij} = f(V_{ij}, X_{ij}, Z_j)$

Where Y_{ij} is quantity produced,

$\mathbf{V}_{ij}$ is a matrix of inputs used by farm manager in household j, including land, labour, capital, and extension advice;

$\mathbf{X}_{ij}$ is a matrix of individual attributes, including gender; and

Z_j are household-and community–level variables. Correlation of input use with individual and household characteristics can be captured by interaction terms V_iX_i and V_iZ_j respectively.

The study used the dual approach to production analysis, it estimates profit function as a function of input and output prices, and derives the input demand and output supply functions from the restricted profit function. This approach has its advantages when there are multiple outputs and inputs, as in a multi-crop farming system. Modelling input choice explicitly also allows for the possibility that farmer characteristic influence the decision making process of conventional inputs.

$Y = \alpha_0 L^{\alpha 1} T^{\alpha 2}$

Where Y is output,

L is labour input (hired or family),

T is a matrix of land, capital, and other conventional inputs which include decision making.

Usually the equation is estimated by ordinary least squares (OLS) by linearizing the Cobb-Douglas production function:

$\ln Y = \alpha_0 + \alpha_1 \ln L + \alpha_2 \ln T + \beta \ln E + \delta SEX + \varepsilon$

Where Y, L, and T are as defined above;

E is educational attainment or indicator variable for level of schooling (of farm manager, or household head);

SEX is the sex of household head or farm manager; and

ε is error term. The coefficient that indicates gender differences in technical efficiency is δ, an intercept shifter

2.1. Conceptual Framework

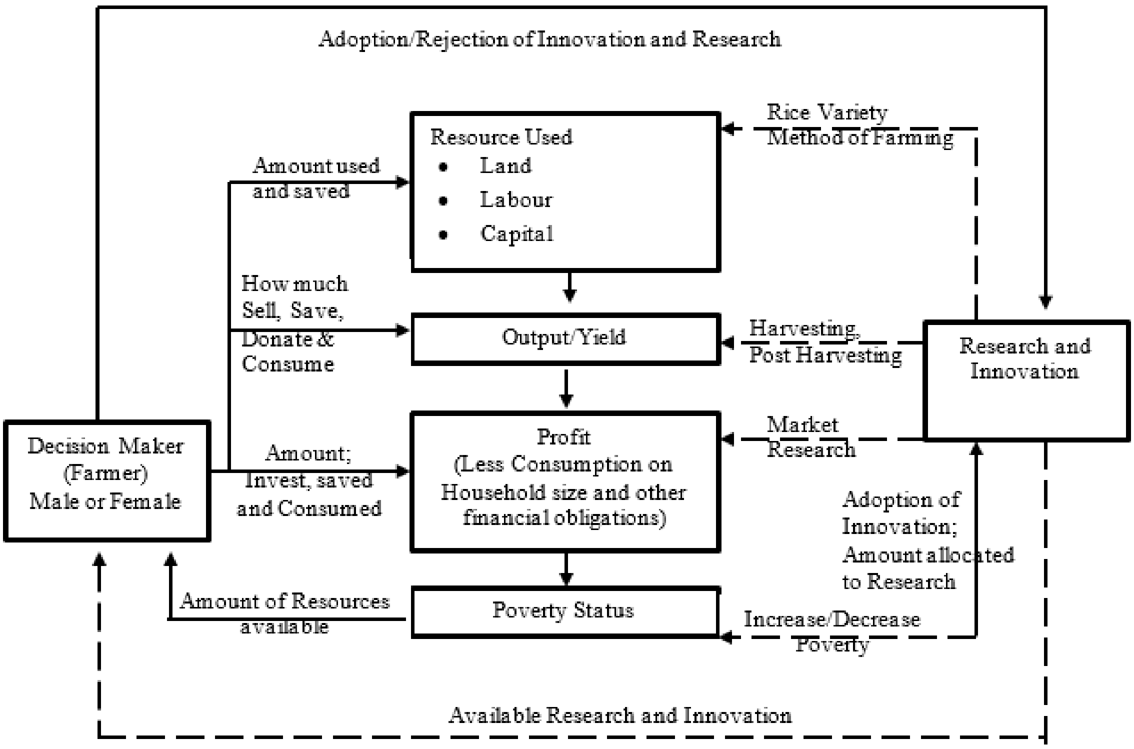

Figure 1. Source (Author, 2013) adapted from Olayide and Heady input-output process (1982)

The concept of this study is presented in Figure 1, agricultural activity as it shown as the combination of resources to yield an output and subsequent profit. These however determine the poverty status of the farmer. Decision maker (which represent the farmer with their respective sex), Research and Innovation envelopes agricultural activities. The effect of farmer's decision on the adoption of Innovation; the use of productive resources; output; profit and subsequent poverty status of any decision maker is represented above with undotted arrows; the effect of Innovation on; productive resources; Output; profit; poverty status; and its subsequent effect on the decision maker is represented by the dotted arrows.

The decision maker make decision on productive resources on the amount of input (Land, Labour and Capital) used, allocation of the output (How much to sell, save, consume and donate), the use of the profit (amount invest and saved) after removing the amount consumed and other financial obligation, the amount left for the farmer now determine the poverty status of the Decision maker (the farmer). The poverty status of the farmer also affects the type of decision that the farmer will make on the next productive cycle in form of the allocation of resources to yield a level of output. In similar way, Innovation and Research affect the amount of resources used; (through improvement in rice seed, planting methods, climatic information etc.) the final output (through harvesting methods, and post harvesting techniques, equipment used to achieve the final output, etc.), the profit (through market information); which later translate to increase or decrease in the poverty status of the farmer.
It also gives to the decision maker ability to choose among available research and innovation which will consequently spur the adoption or rejection of innovations and the use for productive activities and the cycle continues in that order.

3. Methodology

3.1. Study area

The study was carried out in the Nasarawa/Benue rice hub of Nigeria. Rice Sector Development Hubs are zones where rice research outputs are integrated across the rice value chain to achieve development outcomes and impact. The Hub involves large groups of farmers and other value-chain actors, such as rice millers, input dealers and rice marketers (Cisse & Diagne 2012). The rice hub shares in the benefits of the Benue river valley for rice production. The Nasarawa/Benue hub is made up of four local government areas of Guma and Gwer-west in Benue state and Lafia and Obi Local government areas in Nasarawa state. Benue state is located within longitude 7° 47' and 10° 0' East and Latitude 6° 25' and 8° 8' North while Nasarawa state is located within 8°32′ and 8.533°North and 8°18′ and 8.3°East. The states are among the North Central States of Nigeria and are highly agrarian with a large percentage of their populace engaged in rice farming and other agricultural activities. Both states share a common boundary and have rich and diverse agricultural produce.

3.2. Sampling

A three-stage stratified random sampling procedure was used for this study. Local extension offices were visited to collect the list of villages and household in each village in the two states (the hub).Villages where rice is not produced or grown was dropped. The remaining list of villages was stratified based on; dominance of rice production. The villages were grouped into two; (rice in the target ecology as major crop; rice in the target ecology as minor crop). This resulted into two strata. In each stratum, eight villages was randomly selected using Microsoft excel worksheet to form a total of sixteen villages. Within these sixteen villages, ten households was randomly selected with a minimum of three household headed by women giving a total one hundred and sixty respondents (160) and at least thirty per cent of women headed household farmers.

3.3. Source of data

The study used primary data from the NCRI/Africa Rice baseline survey during which tablet computers were used to obtain information from the rice farming households. Africa Rice Centre in 2012 developed the Mlax application in Tablet computers to collect baseline data in the Rice Sector in Africa. The Mlax application is designed with such flexibility such that data collected are automatically sent to a cloud server after connecting the tablets to the internet.

3.4. Method of Data Analysis

Descriptive Statistics was used to investigate the socio-economic characteristics of male headed and female-headed rice farming household and available rice innovation, Likert ranking was done to rank the constraints faced by rice farmers while Least Significant Difference (LSD) was used to test for the significance level of the ordinal ranking of the constraints at 5% level of significance. Women empowerment index was used to examine the participation of women in agricultural decision within the households.

3.5. Likert scale and Least Significant Difference (LSD)

Constraints facing the rice farmers were asked to be listed and the three most important constraints to the farmers was identified in their order of occurrence. The relative frequency with which a constraint was experienced was used to establish its ordinal rank. Least significance difference (LSD) was used to test the ranking for statistical significance using the method represented in pair-wise comparison at 5% level of significant. The LSD expression is given by:

$\text{LSD (at } \alpha = 0.05) = 1.96 \times (SF(n) \times (n+1)/6)^{1/2}$,

Where:

SF was the number of surveyed farmers (disaggregated into sex)

n was the number of ranked constraints.

3.6. Computation of the Women Empowerment Index (WEI) following International Food Policy Research Institute (IFPRI 2011)

The WEI sub-index shows how empowered women are, capturing the roles and extent of women's engagement in the agricultural sector in five domains: (1) decisions over agricultural production, (2) access to and decision-making power over productive resources, (3) control over use of income, (4) leadership in the community, and (5) time use. It assesses the degree to which women are empowered in these domains, and for those who are not empowered, the percentage of domains in which they are empowered.

$$WEI_{all} = \frac{\sum_{j=1}^{n} x_j}{d}$$

Where:

WEI_{all} = women empowerment index for all decisions per respondent
x = value of decision maker
j = code for the specific decision matter
d = total number of decisions replied by the respondent
n = number of decisions.

The value ranges from 1.00 to 5.00

- A value of 1.00 means that the male head tend to be the sole decision maker.
- Any value below 3.00 but higher than 2.00 means that female heads join in making the decisions but the decision of the male head dominates.
- A value of 3.00 means both the female and the male head makes the decision jointly with equal contribution.
- A value near 5.00 and higher than 3.00 means that the female head dominates in decision making than the male head.
- A value of 5.00 means the female head is the sole decision maker.

4. Results and Discussion

Majority of the respondent's household (76.19%) are male-headed, only about 23.81% of the respondents are female-headed suggesting that the involvement of women in rice farming in the study area is low; more than half of the women (54.29%) are without any form of formal education as compared to the men (25.89%). More than half of the male (52.68%) and female (68.57%) farmers do not belong to any form of association. This implies that they do not have the advantages of what groups could offer in term of; training, credits, mobilization of resources and dissemination of necessary information. On the average the rice area cultivated by both male headed household and female headed household are 3.05Ha and 2.58Ha and the mean household is 9 members for male-headed households and 7 for female-headed households. Averagely, 85.71% and 88.59% of male and female rice farmers have access to one form of improve variety or the other as shown in Table 1.

Table (1). Socio-Economic Characteristics of rice farming households

Householdhead Sex	**Frequency**	**Percentage**			
Female	35	23.81			
Male	112	76.19			
Total	147	100			
Male			**Female**		
Age	Frequency	Percentage	Age	Frequency	Percentage
≤30	8	7.13	≤30	0	0
31-40	27	24.12	31-40	3	8.57
41-50	31	27.69	41-50	14	40.01

51-60	24	21.44	51-60	12	34.29
61-70	17	15.17	61-70	5	14.3
≥71	5	4.45	≥71	1	2.83
Total	112	100	Total	35	100
Mean	49.08929		Mean	54.17143	
Std. Dev.	13.64713		Std. Dev.	8.678865	
Membership of Association			**Membership of Association**		
No	59	52.68	No	24	68.57
Yes	53	47.32	Yes	11	31.43
Total	112	100	Total	35	100
Education Level			**Education Level**		
Junior high school	8	7.14	Junior high school	3	8.57
Literate/Koranic	9	8.04	Literate/Koranic	0	0
None	29	25.89	None	19	54.29
Primary	23	20.54	Primary	6	17.14
Senior high school	24	21.43	Senior high school	4	11.43
Tertiary	19	16.96	Tertiary	3	8.57
Total	112	100	Total	35	100
Household Size			**Household Size**		
≤5	27	24.1	≤5	12	34.29
6 – 10	50	44.65	6 – 10	17	48.55
11 – 15	28	25	11 – 15	4	11.44
16 -20	6	5.36	16 -20	1	2.86
≥21	1	0.89	≥21	1	2.86
Total	112	100	Total	35	100
Mean	8.839286		Mean	7.257143	
Std. Dev.	3.960511		Std. Dev.	4.513658	
Rice Cultivated Area			**Rice Cultivated Area**		
≤2	62	55.36	≤2	21	60
3 – 4	31	27.68	3 – 4	11	31.43
5- 6	8	7.14	5- 6	2	5.71
7-8	5	4.46	7-8	0	0
≥9	6	5.36	≥9	1	2.86
Total	112	100	Total	35	100
Mean	3.047411		Mean	2.577143	
Std. Dev.	2.539682		Std. Dev.	2.11338	

4.1. Analysis of Rice Innovation in the study area

Technological Innovation if properly understood from the gender perspective can foster increase in agricultural productivity (Tavya et. al. 2013). NERICA variety is a more recent innovation in the study area. It was introduced by AfricaRice to increase farmers' productivity in an attempt to reduce poverty. This variety has the ability to double farmer's productivity. Lower percentage of the male and female rice farming household use NERICA variety. Table 2 presents gender usage of rice technology and the particular NERICA Variety which is the innovation under consideration in the study area. The result shows that male and female rice farming household considerably uses most of the improved varieties present in the study area. Larger percentage of the surveyed female rice farming households (88.57%) use improved varieties than the male rice farming household (85.71%) 13.39% and 8.57% respectively. Further test shows that there is no significant difference in the use of the NERICA variety by both male and female rice farming households. The implication of this is that innovation in rice farming has not been properly utilized in the study area.

Table 2. Technology and Innovation in Rice Farming

Distribution of Rice farming Household according to the use of All Improved Variety except NERICA				
Gender		Frequency	Percentage	t-value
Female	Non-use	32	91.43	0.118
	Use	3	8.57	
	Total	35	100	
Male	Non-use	97	86.61	
	Use	15	13.39	
	Total	112	100	
Distribution of Rice farming Household according to Use of NERICA Variety				
Gender		Frequency	Percentage	t-value
Female	Non-use	4	11.43	0.383
	Use	31	88.57	
	Total	35	100	
Male	Non-use	16	14.29	
	Use	96	85.71	
	Total	112	100	

4.2. Decision Making Analysis

Level of Women control over productive resources; ownership of the land and other productive assets. Decision making is important in productive process. Ability to make decision as to the use of resource and product from farm is important to know the gender empowerment within the household. Table 3 presents the women involvement about decision making within the household, the decision studied include; control over productive resources (land, capital structures as well as their involvement in decision as to the use, acquisition, rent or sale of such resources); decision of types of variety to be grown by the household and the ecology; plot management (planting, fertilizer application, irrigation, weeding and harvesting); distribution of farm output; decision about income from plot; total household income; other general agricultural decisions.

The result shows that 80.15% of the male have access and solely make decision as touching productive resources as compared to 8.09% of the females. 8.09% of the decisions are jointly made in equal proportion, the decision jointly made by the male and the female in the households but with the male dominating such decisions represent 3.68%. 79.31% of decisions of choice of innovation to be used in rice farming (type of variety and ecology) is solely taken by the male, 0.86% of the decision is made by the female, 7.76% is jointly made with equal contribution from both the male and the female, 2.59% is jointly made with male dominating the decision, 0.86% are jointly made with the female dominating. 81.88% of the plot management decision is solely made by males, 8.70% is solely made by females, 7.24% is jointly and equally made while 2.17% of plot management decision is made jointly but the male dominates. Farmers after harvesting distribute the output into categories; the amount to be sold, the amount to be saved as seed, the amount to be given as donation and the amount to consume within the household. 80.70% of distribution decisions are solely made by the male head, 10.53% are solely made by the female head, 6.14% of such decisions are jointly made with equal contribution, 1.75% is jointly made with the female head dominating, 0.88% is jointly made with the male head dominating. More than half of the decision as touching the income generated from the plot is solely made by male head (80.74%), 8.89% is solely made by the female head; 7.41% is jointly made with the male and female head having the same percentage of contribution. 2.22% of farm income decision is jointly made but the male dominates while 0.74% of the decision is jointly made but with women dominating. On household income, 78.44% of the income decisions are solely made by the male head, 10.34% of the decision is made by the female head, 6.90% are jointly decided, 2.59% are jointly made with the male dominating and 1.74% are jointly decided with the female dominating. On the general agricultural decision made, 76.60% of agricultural decision is made by solely by male head, 7.80% of agricultural decision is solely made by female, 7.09% of the agricultural decision is made jointly by both male and female head of the household. Decisions made jointly by the male and the female household head with male dominating such decision represent 6.38% while only 2.13% of the household decision as related to agricultural activities are jointly decided by females with males dominating. The result of the women empowerment index shows the marginalization of women in decision making as touching agricultural activities in the household. These results agree with (Rahman, 2008; Ani, 2003)

Table 3. Results of the Women Empowerment Index (Decision Making)

Decision Making About;	Freq.	Percentage	Cum.
Productive Resources			
Male Alone	109	80.15	80.15
Joint but male Dominating	5	3.68	83.82
Joint with equal contribution	11	8.09	91.91
Female alone	11	8.09	100
Total	136	100	
Choice of innovation			
Male Alone	92	79.31	79.31
Joint but male Dominating	3	2.59	81.9
Joint with equal contribution	9	7.76	89.66
Joint with female dominating	1	0.86	90.52
Female alone	11	9.48	100
Total	116	100	
Plot management plot			
Male Alone	113	81.88	81.88
Joint but male Dominating	3	2.17	84.06
Joint with equal contribution	10	7.25	91.3
Female alone	12	8.7	100
Total	138	100	
Distribution of output			

Male Alone	92	80.7	80.7
Joint but male Dominating	1	0.88	81.58
Joint with equal contribution	7	6.14	87.72
Joint with female dominating	2	1.75	89.47
Female alone	12	10.53	100
Total	114	100	
Distribution of income from plots			
Male Alone	109	80.74	80.74
Joint but male Dominating	3	2.22	82.96
Joint with equal contribution	10	7.41	90.37
Joint with female dominating	1	0.74	91.11
Female alone	12	8.89	100
Total	135	100	
Household income			
Male Alone	91	78.45	78.45
Joint but male Dominating	3	2.59	81.03
Joint with equal contribution	8	6.9	87.93
Joint with female dominating	2	1.72	89.66
Female alone	12	10.34	100
Total	116	100	
General agricultural practices			
Male Alone	108	76.1	76.6
Joint but male Dominating	9	6.3	83
Joint with equal contribution	10	7	90.1
Joint with female dominating	3	2.1	92.2
Female alone	11	7.7	100
Total	141	99.3	

5. Summary and Conclusion

The study revealed that despite the available rice technologies present, the use of recent rice innovation (NERICA variety) by farming household is low; Technological interventions aiming to improve livelihoods that bring gender equity can become successful only when the prevailing gender roles in society and access to different livelihood opportunities are fully understood. Aside households whose head are majorly women, the result of the women empowerment index women are not justifiably included in decision making as touching agricultural activities in the household. It is therefore recommended that if progress will be made in rice production across the value chain, innovation usage should be properly advocate, subsidy should be intensified and women consideration in decision making to foster their empowerment should not be a matter of propaganda in policy, it should rather be a priority.

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