Food Security Modeling Using Geographic Information Systems (GIS) Techniques: A Strategy Towards Reliable Food Security Information & Early Warning Systems (FSIEWS) For Tanzania

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ABSTRACT*:*

The practice of food security assessment in Tanzania is based on use of food crops production data surveys of a preceding seasonal year with agro-meteorological analyses based on estimated vegetation status as reflected from NDVI computed from NOAA satellite images. Food security assessment essentially is a prediction of food availability in predefined future time framework. It helps to establish availability or deficiency of food, thereby facilitating planning and implementation of strategies to mitigate the problem of hunger. The practice of food security assessment in Tanzania, has following shortcomings: the results of prediction are unreliable due to use of coarse metrological data, it is inefficient as it takes a lot of time to do data compilation and analysis, it is difficult and relatively expensive as it involves physical visiting of villages, districts and regions by agricultural officers to collect food crops production data. The above shortcomings can be reduced by adoption of GIS Techniques.

This paper is reporting on a research conducted to model the process of food security assessment using Geographic Information Systems (GIS) tools, it is based on representing data pertaining to pillars of food security which are food availability, food accessibility and food utilization/nutritional capacity in form of GIS layers and integrating them. The collected food security pillar data were firstly transformed into respective point layers and secondly down scaled through re-sampling and interpolation by the Inverse Distance Method creating 30 m by 30 m pixel size raster layers. Resulting layers were then integrated through logical overlaying with a population layer, creating a Food Self Sufficient Ratio layer which was classified to form a Food Security Map for Tanzania.

It is being concluded that application of GIS modeling approach is relatively faster and convenient than statistical manual methods, food security Information ought to be executed readily, so as to facilitate evidenced-based understanding of food imbalances, thereby guiding administrators in decision making with regard to designing of equitable methods of surplus food distribution to the needy or to local and/or lower levels.

Keywords: Food Security, Food Security Information and Early Warning Systems, Food Crops GIS Data Layers, Overlaying, Food Self Sufficient Ratio

INTRODUCTION

Food Security is defined by the World Food Forum 2006 as "A situation of whereby all people have access to sufficient, safe and nutrious food at all times to maintain healthy and active life".

Achieving food security in its totality continues to be a challenge not only for developing countries, but also for the developed world. The difference lies in the magnitude of the problem in terms of its severity and proportion of the population affected. While in developed nations the problem is alleviated by providing targeted food security interventions, including food aid directly, or indirectly through subsidized food production. These efforts have significantly reduced food insecurity in these countries. Similar approaches are employed in developing countries but with less success. The discrepancies are mainly due to insufficient resource base, shorter duration of interventions or different systems most of which are inherently heterogeneous among other factors. Underlying pillars of food security are:

(i) Food Availability i.e. Adequate quantities of food are available to people on a consistent basis

(ii) Food Access i.e. People to have sufficient resources (physical and economic) to obtain appropriate food for nitrous diets and

(iii) Food Utilization i.e. People to have sufficient and care practices and access to adequate water to derive sustenance food (Masalawala R.et al, 2010)

The need for development of Food Security Information and Early Warning Systems has reference to the 1974 World Conference in Rome, which adopted the 'Universal declaration to eliminate hunger and malnutrition" (*ratified in by the World Food Summit in 2006*). At that time, analyses of the causes of hunger arose and the idea of "Food Security"developed, followed by creation of the World Food Security Committee (WFSC). Governments were then urged to set up Food Policies and the emphasis was placed on trying to balance the supply and demand for staple foods. Food-supply monitoring systems were gradually developed during this period (FAO, 2000). Public Marketing Offices were mandated then to supervise the supplies and efforts were made to create national and regional food security stocks (particularly in dry prone areas) for use in events of food crises. In this set up, information regarding food production, national supplies, stocks and food imports were under custodian of the public Marketing Departments.

Data collected by Public Marketing Departments were, in turn, supplied to respective Statics Departments, which in turn also after synthesizing the data and supplied information for national planning and economic monitoring officers. Supplied information by the Statistics Department weren't very useful for monitoring food security. This was due to the fact that the provided information was based on unreliable statistics which took long time to establish and areas covered oftenly were incompatible making it difficult comparing it with datasets gathered from other systems. This resulted in a situation whereby development partners who are the main sympathisizers in this regard, with their initiatives to help countries at great risk of hunger in particular those in the Sub Sub-Saharan Africa were obliged to establish parallel Information Systems that they finance and supervise and that which provide them in good time information they need to target their food security aid and assistance to specific needy locations. Some of the factors affecting food security among others are as follows

(i) Structural Adjustment and Privatization programmes which have been adopted by Tanzania and most developing countries have radically changed economies of those countries with major repercurssions on food security. To that effect the issue of access to staple food and/or poverty alleviation needs to be examined much more closely with guided specific information. .

(ii) Diminishing World grain Surplus due to such effects as climate changes have led to the International community reducing food aid to developing countries, indeed questioning the use of the aid to that effect, which if used unsuitably or mismanaged can cause negative effects on food security. In this regard, existing Food Security Information Systems and Early Warning Systems serves to assess the status of food security and identification of vulnerable groups at urban as well as rural levels.

(iii) Globalization is strongly linked to the pace of being able to use modern communication technologies. Such as the Internet, Satellite Communications, Fax, Mobile Phones etc. and management systems (computers). It is now much easier to manage databases, forecast and disseminate results. Food Security Monitoring and forecasting systems have become at least in theory, they are easy to manage in national contexts. indeed, the International Community as whole is in favor of training of managers to user modern tools and media.

PROBLEM STATEMENT

Much as pillars of food of security are all important some are primary while others are secondary. As such, it is not logical according all pillars same level of priority when assessing food security. For example food availability is relatively critical than others as it directly affects food security in the sense that it is a foundation of other pillars, as it fosters production of more food thereby, effectively, reducing poverty through improving incomes of producers or farmers, so this pillar deserves relatively more priority than the rest of the pillars in assessing food security. In that regard information about areas expected to have more food production or surplus ought to be known so that the surplus food may be distributed promptly to areas expected to have low food production. This is without consideration to salient constraints due to such factors as:

(i) Poor Infrastructure - which may hinder easy access to areas of high or low food production

(ii) Non supportive local policies and legislations: For example existence of policies and regulations which do not promote food security in totality. For example, etcpolicies which restrict free movement of food from one point to another etc.

(iii) Information about the status of food availability in terms of surplus and deficiency at a national level is mandated to the Ministry of Agriculture, Food Security and Cooperatives. Processing of this information is usually done manually at the Ministry and results are given only published once per annum. Food availability information ought to be provided readily so as to stimulate farm business and fostering design of effective approaches to equitable distribution of food to needy areas.

Food utilization, the second pillar in order of priority is determined by food consumption rate. In turn this is dependent on population. The third pillar in priority is food accessibility which is about the economic accessibility strictly speaking this about people's purchase capacity and physical accessibility to available food.

Food Security assessment essentially boils down to prediction of food production availability for a given future period of time, among other things it involves spatial identification of areas expected to have food surplus as well as areas expected to have low food production in the pre-described future time frame so as to facilitate equitable food distribution to the people when that .time is due. The following systems exist for food security assessment:

(a) Agricultural Production Monitoring(APM), normally this is combined with monitoring the products of livestock farming,

(b) Market Information System (MIS), this is usually monitors domestic trade and sometimes international trade (Imports/Exports),

(c) The social Monitoring of the most vulnerable populations or monitoring of vulnerable groups. This focuses on monitoring of poverty prone areas,

(d) Food and Nutritional Surveillance Systems (also called food and nutrition monitoring) FNSS, which generally, depends on the situation, it monitors the health and nutritional status of populations

In Tanzania food security assessment practice is based Agricultural Production Monitoring (APM) which is effected manually using statistical food crop production surveys data of a proceeding year combined with agrometrological analyses based on expected vegetation status from NDVI images as derived from NOAA satellite images.

The above practice has shortcomings such as: the results of the prediction are unreliable due to use of coarse metrological data, it is ineffective as it involves physical visiting of agricultural officers to villagers, districts and regions to collect food production data, the practice is expensive as it takes more time to do compilation and analysis. All these short comings can be addressed through automating the food security assessment process by using Geographic Information Technology (GIS) tools.

The aim of this research was to that effect to model the process of food security assessment and early warning systems using GIS techniques.

ADVANTAGES OF FOOD SECURITY INFORMATION AND EARLY WARNING SYSTEM

(i) It conforms with globalization of information

(ii) It is compatible with the food monitoring framework as set by the World Food Summit(2006)

(iii) It is simple, easy to use and is scalable as it is easily to integrate with other datasets

(iv) It fosters major humanitarian initiates stewarded by the United Nations such as Combating Abject Poverty Reduction, Disaster Relief Missions, Equity Distribution of needs to flood victims etc

GIS OVERVIEW

There exists many GIS views in literature, for the purpose of this paper the technological view point as proposed by Aronoff, 1991.is adopted, which describes GIS as a technology that automates collection and integration of multi-source spatially and temporarily referenced data sets and performs analytical operations on the data. Indeed, it is a technology that fosters efficient and accurate analysis of vast amounts of data and modeling of complex natural or artificial induced phenomenon using mathematical and logical operations. In principle, any GIS is capable of collection, storage, and analysis of data about objects and/or phenomena where location is an important characteristic or critical to the analysis. Additionally, GISes are capable of integrating spatial and other kinds of datasets within a single system. Indeed they offer a consistent framework for analyzing geographical data by generation of maps and other kinds of information in digital form.

GIS tools have been used in such practices as evaluation of management practices for grazing land, tracking of grazing area types and intensity overtime and collecting data on vegetation

condition and weather data, grazing practices can be assessed and improved (Graetz et al, 1986 in Aronoff, 1995). GIS techniques are recommended by FAO and have potential for application in food security assessment, though their operationalization in developing countries are hampered by lack of adequately trained personnel, hardware/software and reliable data

METHODOLOGY

Tanzania Administrative areas were digitized from an existing Topographic Map of Tanzania in Shape file format of ARCGIS (9) software used in this research. Administrative areas polygons were each converted into points form by converting them into respective centroid expressed in terms of X, and Y. The yield for each food crop which were initially in Excel format were imported into ARCGIS as attribute values and assigned to respective Administrative area polygons.

With regard to food availability pillar, this was modeled as a combination of all food crop production data under consideration which were Maize, Cassava, Beans, Potatoes, Bananas, Millet, Sorghum, Rice and Wheat, these were then treated as attribute values and assigned to respective administrative area polygons, resulting in respective food crop point layers. As subsequent overlaying process was to be done in the raster format and with the view that results could be integrated with other data sets such as satellite images, it was prudent then for all point layers to be rasterized and re-sampling at a pixel size of 30 by 30m followed by downscaling by interpolation by the Inverse Distance Method.

With regard to food utilization pillar, this is about people's ability to have sufficient and care practices for accessing adequate water and deriving sustenance food. Underlying factor of this pillar is food adequacy or requirement. Food adequacy is a function of population which depends on individual consumption rate. Areas

Population estimate for 2010/11 was obtained from the National Bureau of Statistics and was used as attribute data for respective administrative areas. The population data was transformed into a point layer, which was later rasterized re-sampled to 30m pixel size and down scaled to and downscaled through interpolation leading to raster population layer.

With respect to food accessibility layer, this layer had two facets which are physical and economic. As there was no data for modeling of people's economic food accessibility or specifically peoples purchasing capacity, this layer pillar was not modeled thus, for purpose of this research it was not considered.

As food security assessment indirectly requires establishment of food utilization capacity which is very much dependent on consumption rate, population and food available With Food availability, and population all down scaled to 30m pixel size the Food Self Sufficient Ratio (SSR) was computed using the following mathematical model:

$$SSR = \frac{FOODAVAILABLE}{REQUIREMENT = PopulationXConsumptionRate}$$

Classification of areas into either Food Self Sufficient or Surplus Food or Food Deficiency Areas was done on the basis of the following:

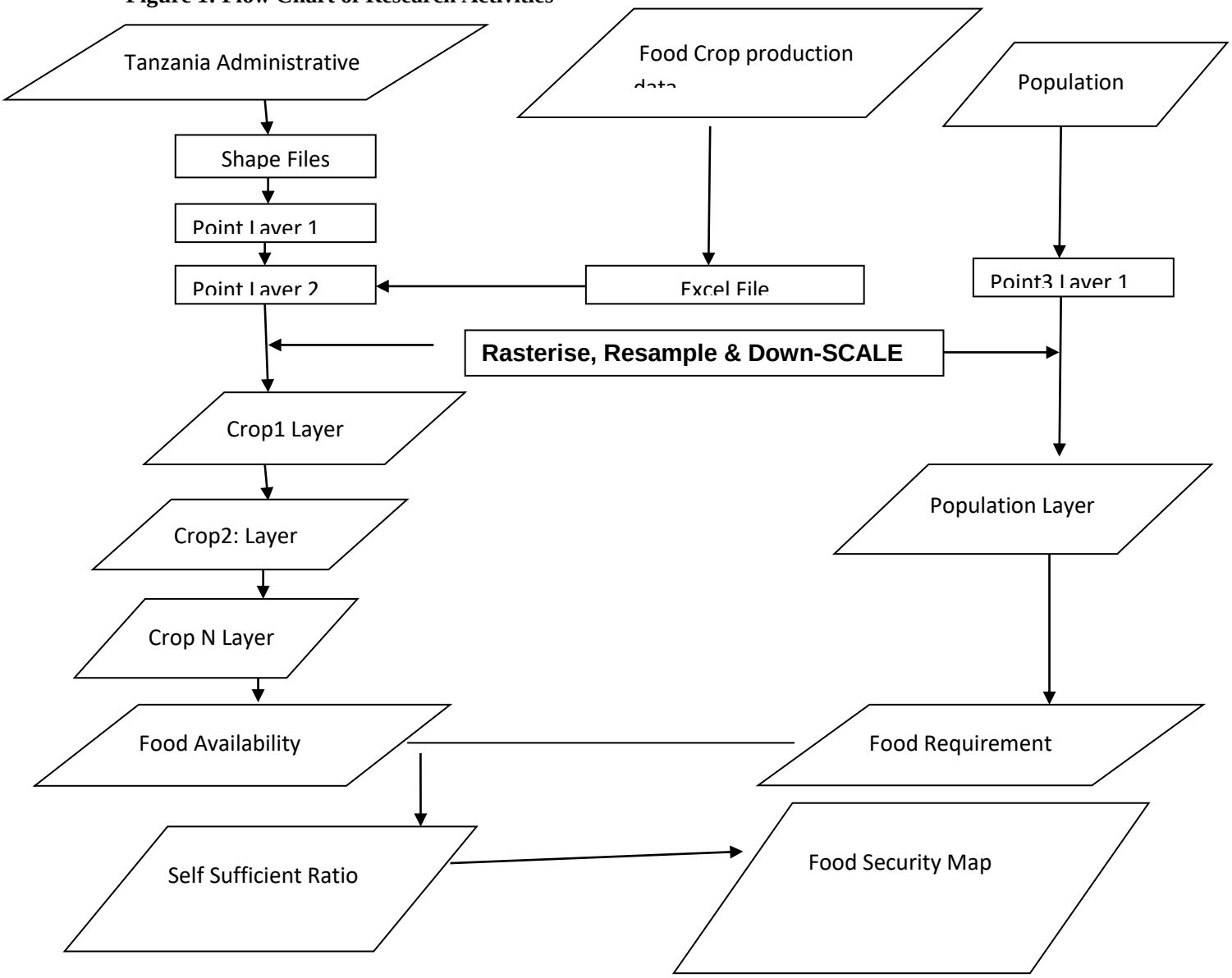
(i) If 100% < **SSR** < 120 % - Area with Food Self Sufficiency,

(ii) If **SSR** > 120 % Area with Surplus Food,

(iii) If **SSR**< 100 % Area with Food Deficit

The full methodology is as presented on Figure 1 below.

Figure 1: Flow Chart of Research Activities



Source: Own Construction

RESULTS

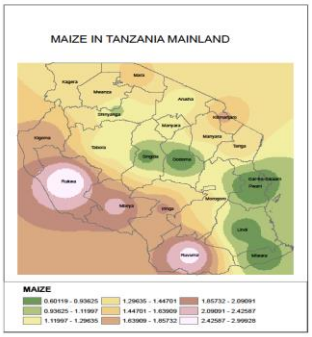
Operationalization of the above methodology, gave following results:

Food Availability:

9 food crop raster layers were generated as shown below:

Fig.2: **Food Crop Layers**

(a)



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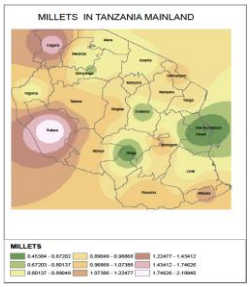

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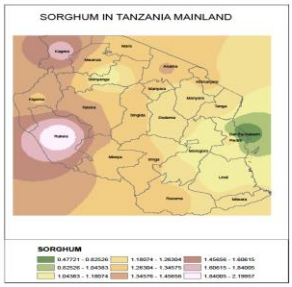

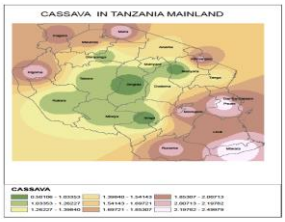

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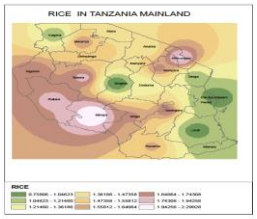

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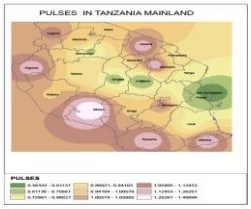

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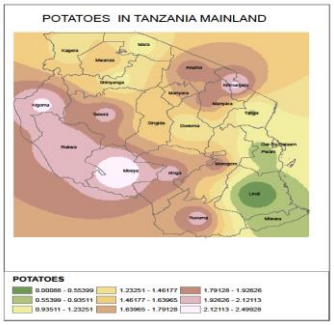
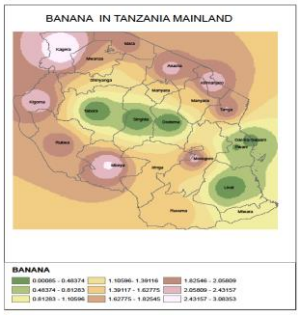


(g)



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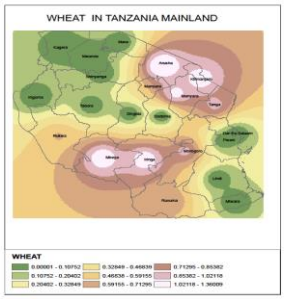


(i)

Fig.3: Food Availability Layer

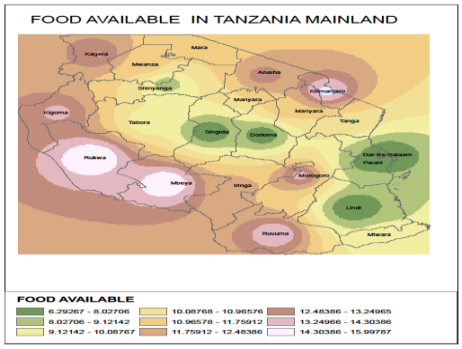
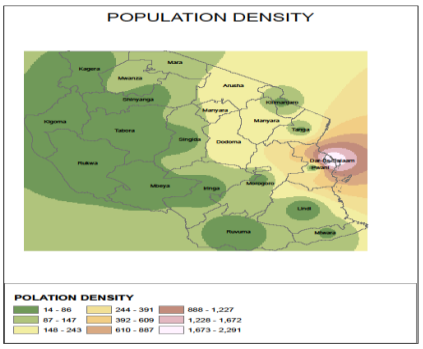


Fig 4: Population Layer



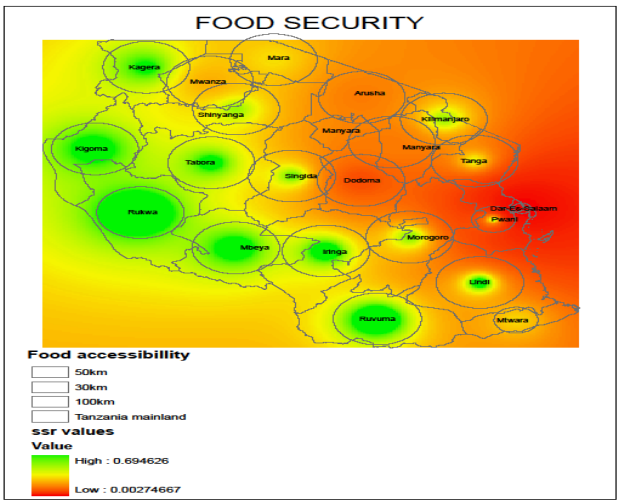
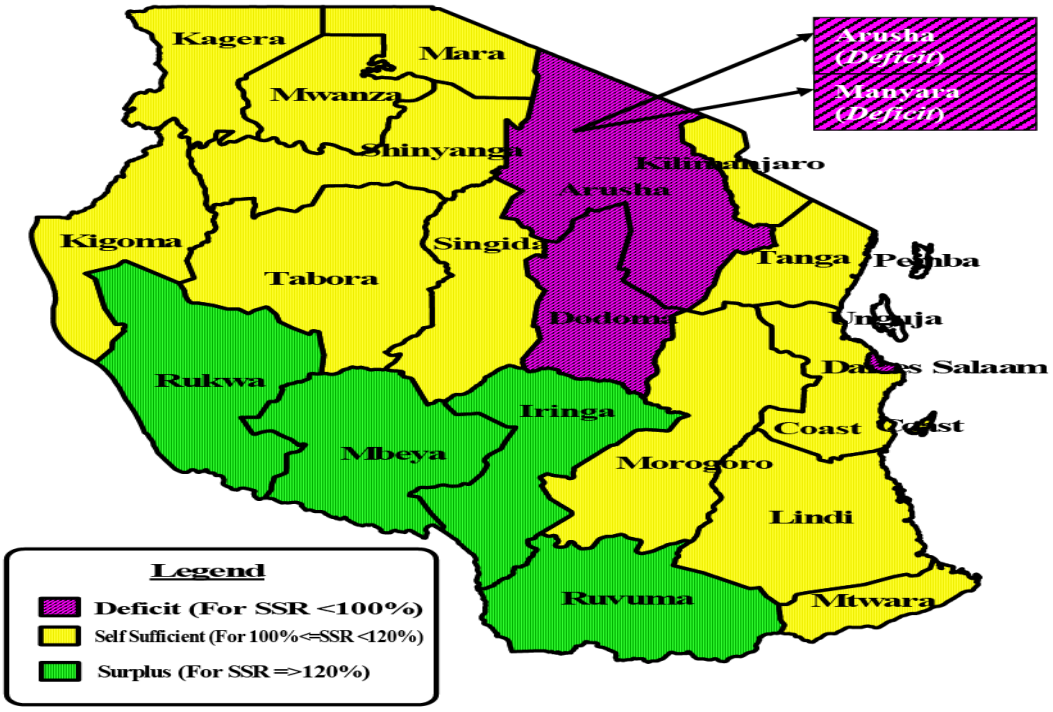


Fig 5: Food Security Map 1

Crop Monitoring and Early Warning

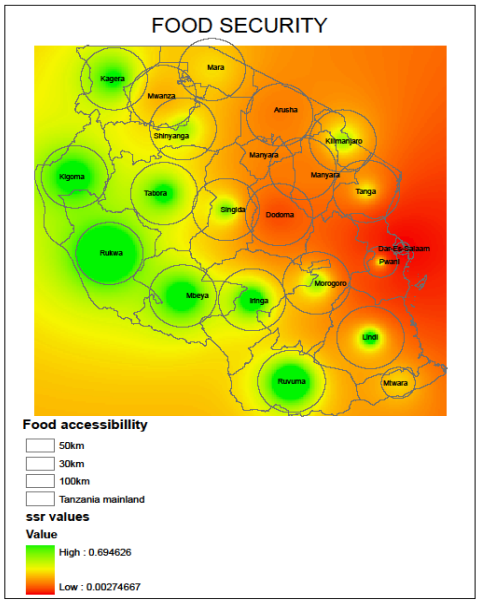
Figure 6: Total Food Supply Forecast for the 2010/11 Marketing Year(based on 2009/2010 food crop production forecasts)

Final Forecast of Food Security for 2010/11



Source: Ministry of Agriculture Food Security and Cooperatives(2010)

Figure 7: Food Security Map (10-11)



Source : Ministry of Agriculture &Food Security (2010)

8. RESULTS ANALYSIS

Results analysis was based on conformity between the GIS derived Food security Map (Fig.5) and the statistically (manual) derived Food Security Map as adopted from the Ministry of Agriculture (Fig.6). There is a great conformity in the two maps in terms of the areas with food surplus, sufficient as well as those expected to experience food deficit. This testifies the fact modeling the Food Security Modeling has been achieved correctly.

9. CONCLUSIONS

From this research the following can be concluded regarding modeling of Food Security assessment using GIS techniques:

(i) Food security assessment using GIS modeling is relatively faster and convenient

(ii) Food Security prediction through GIS modeling is highly scalable thus potential for integration of other related datasets e.g. from emerging satellite images with enhanced high spatial and radiometric resolutions into the prediction process which all together can improve the reliability of the results.

10. RECOMMENDATIONS

Now that Tanzania has embarked on initiatives to use benefits brought about by the ICT, specifically connecting all regional centers to the national Fibre Optical Network. The struggle should be to link all districts and if possible wards. In the event of that, food crop production data can be accessed easily and subsequently food security information can be easily communicated to focal responsible offices for instantly processing. In the view of that, as the systems requires an ordinary computer to run with a basic GIS software package, it is possible to use it to set up a full time Food Security Early System. This can promote farm business and reduce poverty to peasants.

REFERENCES

Aronoff, S., 1991, Geographic Information Systems: A management perspective, WDL, Canada

FAO, 2000, *Handbook for Defining and setting up a Food Security Information and Early Warning System (FSIEWS)*

Food Crop production forecast 2010/2011."Ministry of Agriculture Food Security and Cooperatives

Masawala, R., A. F. Shapiro, M. Ingham, B Rinehart, Z. Nazir, G. Bastian, X. Wang, G. Armenta, C. Thompson, C. Stone, (2010), " Food Security in Tanzania: Enabling Environment, Opportunities and Constraints, Spring Semester Paper (2010) at Columbia University/SIPA supported