Use of Goeinformatics in 3D Participatory Land Use Planning for Strengthening Land Management- A Case Study of Darfur Region

Mahgoub Suliman Mohamedain[1], Eltaib Saeed Ganawa[2], Mohamed Salah Eldin Kinin[3], Adam Abdalla Adoma[4]

[1]Associate Professor- College of Forestry and Range Science, Sudan University of Science and Technology -P.O. Box 6146,. Postal Code: 11113, Khartoum, Sudan
mahgoubsul[at]yahoo.co.uk

[2]Associate Professor - Faculty of Art-University of Khartoum-P.O. Box 321, Khartoum. Postal Code: 11115

[3]Assistant Researcher-Agricultural Research Corporation, Nyala-Sudan

[4]Assistant Prof. Faculty of Agriculture, Sinar University- Sinnar State-Sudan

Abstract: *Participatory Land Use Planning (PLUP) has been launched as a modern tool for sustainable resource management in rural communities in the last three to four decades. PLUP is a top-down management approach deals with integrating geoinformatics technologies such as aerial photos, Geographic Information Systems and Global Positioning Systems into land use planning and natural resources management by local communities. Due to the conflicts in Darfur region, natural resources faced many environmental challenges such as overexploitation, population growth, displacement, resettlement and others. Therefore, this research was an attempt developed to assess, evaluate and document implementation process of the 3D PLUP experiences in Darfur region used for strengthening natural resources, land use management and planning carried out within a frame of series of workshops and activities conducted by the author for FAO in Darfur region during the period 2017-2019. The research was of two components, one dealing with description, documentation and assessment 3D PLUP model construction and use, while the other part represents the respondent's questionnaire designed to evaluate the views of the intended communities about the PLUP mechanism. The process started with the socioeconomic data collection through meeting, group discussion and awareness workshops with intended communities where the existing natural resources status and environmental challenges were been described and then agreed upon having a PLUP model as a mechanism for strengthening the land management. Then after a land management committee in each area has been selected and trained for construction of the 3D/2D PLUP model. Afterward topographic DEM and maps were produced in GIS and printed in as analog maps. Then after the communities constructed the 3D/2D models depending on the contour and relief model using set of materials described in this research. As a result in this research one to two 3D models were constructed in eleven municipalities in Darfur region. The results showed that more than 70% of the participants found the 3D/2D PLUP models were useful in strengthening land management in the studied areas. Also, nearly all respondents mentioned that many environmental challenges were existed in the areas and it is wise to have such kind of mapping model. Moreover, almost all participants said they didn't hear about the PLUP model before. In the same time more than half of the respondents mentioned that the construction procedures of the 3D PLUP model were easy to understand and middle in difficulty. The study concluded that the 3D PLUP model was helpful, socially acceptable and scientifically wise approach in strengthen and enhancement of land management in the studied areas and recommended to be replicated in the other localities and states in the country.*

Keywords: Goeinformatic, 3D Mapping, Participatory, Land Use, Planning, Management, Darfur

3D Participatory Land Use Planning (PLUP) Approach for Strengthening Land Management

The research is aiming to assess, evaluate and document the use of the 2D/3D PLUP experiences in Darfur for strengthening land management. The study is partially based on experiences, activities and reports of the participatory workshops of the 2D/3D PLUP map and models carried out in eleven localities in four states in Darfur region. The structure of the research as follows:

Nomenclature
ASTER: Advanced Spaceborne Thermal Emission and Reflection
2D/3D: Two or Three Dimensional
DEM: Digital elevation Model
FAO: Food and Agricultural Organization of the United Nation
GIS: Geographic Information Systems
GIT: Geographic Information Technologies
MDGs: UN Millennium Development Goals
PLUP: Participatory Land Use Planning

WSIS: World Summit on the Information Society
Further nomenclature continues down the page inside the text box

1. Introduction

Geographic Information Systems (GIS) and Geographic Information Technologies (GIT) are increasingly employed in researches and development projects that incorporate community participation approaches, (William, et al. 2002). Also, Shalini, (2005) stated that Geographic information and spatial data have played an increasingly important roles in development planning and environmental decision making from top-down management to grass-roots participation, to facilitate participatory development that is both inclusive and environmentally-sensitive. The international demand for these technologies were been discussed in several initiatives, such as the UN Millennium Development Goals (MDGs) and the World Summit on the

Information Society (WSIS) in which has been emphasized that an effective development depends on equitable information access and global knowledge sharing (UN MDGs, 2015 and WSIS, 2003). Not only that but also PLUP assists land users in selecting options that increase their productivity in sustainable base and meet the needs of society (FAO, 2013). Therefore, Carola, 2003 stated that participatory land use planning and land allocation are a prerequisite for sustainable land use planning.

The research is aiming to assess, evaluate and document the use of the 2D/3D PLUP experiences in Darfur for strengthening land management. The study is partially based on experiences, activities and reports of the participatory workshops of the 2D/3D PLUP map and models carried out in eleven localities in four states in Darfur region. The workshops activities were include training of communities in building a 2D/3D PLUP model for the natural resources in the area, focus group discussion to collect the relevant then given a series of presentations on the status of those natural resources and challenges facing. After that the communities discus the challenges and draw their opinions and recommendations for planning of natural resources use and decided what to be add to the map. For the natural resources a GIS and DEM maps were produced using a real filed data from the NRDB database and ASTER DEM satellites. Furthermore, a respondent's questionnaire has been designed to get the views of the communities about the PLUP models after implementation of the mechanism.

1.1 Objectives

- To assess, evaluate and document the 3D PLUP approach and techniques implemented in Darfur region during the period 2017-2019.
- To investigates the usefulness of the 3D PLUP model in strengthening natural resources and land use management on sustainable basis
- To assess the effectiveness of satellites images and DEM maps in strengthening land management planning.
- To assess whereas PLUP is socially acceptable and environmentally sound approach in strengthening land management.
- Furthermore, to set procedures for best implementation of the 3D PLUP technique.

1.2 Problem and Justification

Due to the conflicts in Darfur region, existing natural resource especially those in rural areas exposed to several environmental challenges such as degradation, overexploitation, population growth, displacement, resettlement and other factors. As consequences conflicts emerged over available natural resources and competing claims to the land allocation or re-allocation. This led FAO and other NGOs in the region to adopt an implement a 3D/2D PLUP techniques in Darfur to assist local communities for strengthening uses and planning of natural resources. Although, PLUP experiences gathered in Darfur were useful, but still very limited in scope and methodological framework, because PLUP approach in Darfur specifically and Sudan as whole remains largely unknown to most of staff, academicians and specialists involved in land use planning. Therefore, there is a perceived need for providing in-depth knowledge and analysis to the 3D PLUP system used in Darfur and further to set procedures for best use and implementation of the 3D PLUP techniques, since without such knowledge and evaluation, use of the PLUP techniques for land use planning and natural resources management would be short-sighted.

2. Materials and Methods

The materials and methods of the research in addition to the study area has two components; part one dealing with the materials, tools and methods used for building the 3D/2D PLUP model and part two was the respondents questionnaire designed to assess the views of communities after implementation of the 3D/2D PLUP approach.

2.1 The study Area

The study area represents selected 11 localities in four States in Darfur from which FAO implemented the 3D PLUP programs during the period 2017-2019. The localities were namely; Alsalam, Geriada, Tulus, Merching, Belail, Kass and Niteaga in South Darfur; Wadi Azum in Central Darfur; Jebel Moon and Kulbus in West Darfur and Mellit locality in North Darfur state, (Figure 1).

2.2 Materials and methods for Construction of the 3D PLUP Model

Design and construction of the 3D/2D PLUP model represents a main component of the PLUP approach and process. With regard to this research we used the PLUP model construction steps and mechanism modified from Bourgoin (2011), (Figure 2). The process started with awareness workshops for the intended communities including local leaders and all stakeholders. During that event, natural resources status and environmental challenges were been explained, discussed and analyzed. Then after the 3D PLUP approach has been presented and explained as a modern tool and mechanism used for strengthening natural resources management. Afterward, a land management committee in each area was selected and trained for construction of the 3D PLUP model or 2D in some areas. From technical side GIS maps of natural resources from NRDB database, Landsat8 and ASTER DEM satellites have been produced in lab and printed out in analog copies for the 3D models. Topographic maps and GPS points also have been collected and used for delineation of the localities and study areas boundary. Then later for transfer of the analog GIS map to a 3D model, layers of cardboard were cut along contour lines and pasted one after another onto the base board beginning with the lowest altitude and finishing with the highest altitude. Communities are free to add whatever they need from features they already discussed and agreed upon to the model such as animal routes, newly grazing areas etc. Finally, sticky tapes and plaster bandage strips were added to the relief model to create an overall smooth surface. Finally the 3D PLUP model presented to the whole village, explaining the features, agreed upon and then handed over to the head of the municipality, (Figures 2 & 3).

2.3 Respondents Questionnaire and Sampling

A respondent's questionnaire has been designed to assess the views of communities after implementation of the 3D/2D PLUP models in order to inspect community's views upon the PLUP approach in strengthening land management. The sample size was divided by equal proportion in the 11 localities using Equation 1 & 2 bellow with confidence level of 95%. Accordingly, the sample size was calculated to be 191 participants, but due to COVID-19 it was been able to reach 134 participants and 9 localities out of 11.
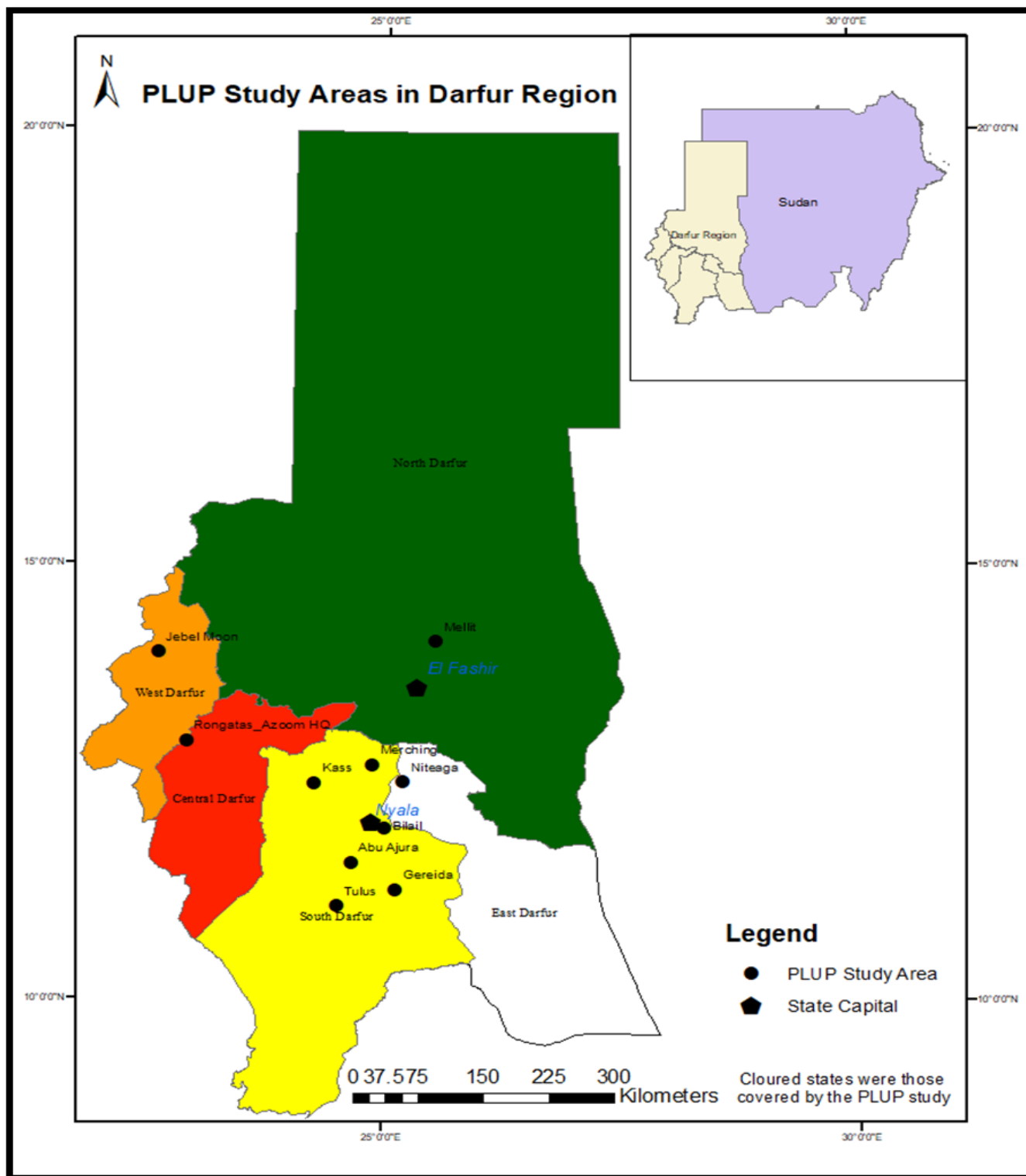
Figure 1: PLUP Study Areas in Dar-(Source NRDB, Field GPS & Google Earth)

Sample Size Calculation Equation

$$ss = \frac{Z^2 * (p)*(1-p)}{c^2} \qquad \text{(Equation 1)}$$

$$\text{Sample size } (n) = (ss/ (1 + (ss-1)/ pop)) \qquad \text{(Equation 2)}$$

$Z = $ Z value (e.g. 1.96 for 95% confidence level).
$p = $ Percentage picking a choice, expressed as decimal (0.5 used for sample size needed).
$c = $ Confidence interval, expressed as decimal (e.g., .05 = ±5). $pop = $ Population
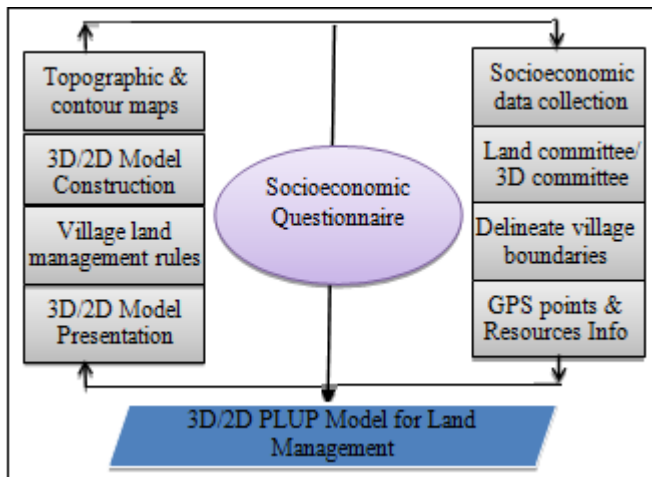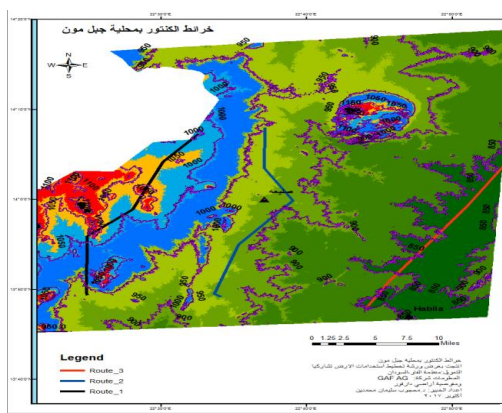
Figure 2: 3D PLUP model methodological framework modified from Bourgoin (2011)

1. Meeting community and discussion of land use plan   2. 3D construction materials

3. Train 3D Committee and start construction process   4. GIS DEM and contour map

5. Fixed the GIS map of the resources and trace   6. Final 3D base process –fixed carbon paper
Figure 3: PLUP 3D Building Process

3. Results and Discussion

3.1 Introduction

The results of the study were the 3D/2D PLUP models constructed by the communities during the participatory land management workshops in addition to the questionnaire results. To be noticed the research activities covered 11 localities in four Darfur states, but for the purpose of this paper a results of one locality per each state will be presented. While the questionnaire results will be for the 9 localities covered in the four states.

3.1.1 Alsalam Locality South Darfur State:

The 1st 3D PLUP model built was for the land use and soil types of Alsalam locality in South Darfur State as sample from analog GIS map covering an area of 40 X 40 km (160000 ha) (Fig. 4). Only land use and soil maps were chosen for the 3D PLUP training workshop because land system of the area showed domination by degraded sand sheet and dune complex on considerable flat to gently undulating pediplains and flood plain complex within confined valleys. These land systems and soils were the mostly used for rainfed agriculture, vegetation and rangelands. Not only that but also the local community interest was to strengthen management and use of these soil types and land use. Furthermore, the community has been trained in how to update the 3D map features in the model as

needed in the future. Accordingly, the 3D PLUP approach was useful in showing these features and addressed the environmental challenges nearly mentioned by all participants (table 1). Not only that but also more than 70% of the respondents said that the 3D PLUP approach was useful in dealing with the land management challenges and the model construction techniques was middle in difficulty (Table 2, Fig. 4 & 5).

Table 1: 3D PLUP Model Dealing with Environmental Challenges

| Locality	State	Environmental Challenges		Environmental Challenges %	
		Yes	No	Yes	No
Alsalam	South Darfur	15		100%	0%
Bilail	South Darfur	17		100%	0%
Greida	South Darfur	17		100%	0%
Kass	South Darfur	16	1	94%	6%
Merching	South Darfur	16		100%	0%
ALL		81	1	99%	1%
Azum	Central Darfur	14		100%	0%
J.Moon	West Darfur	9		100%	0%
Kulbus	West Darfur	17		100%	0%
All		26		100%	0%
Melllit	North Darfur	11		100%	0%
All States		132	1	99%	1%
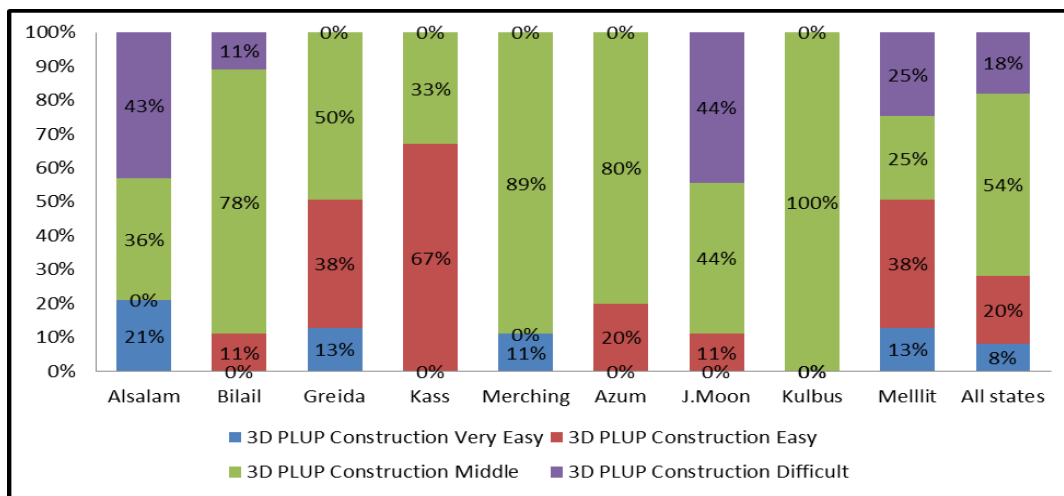
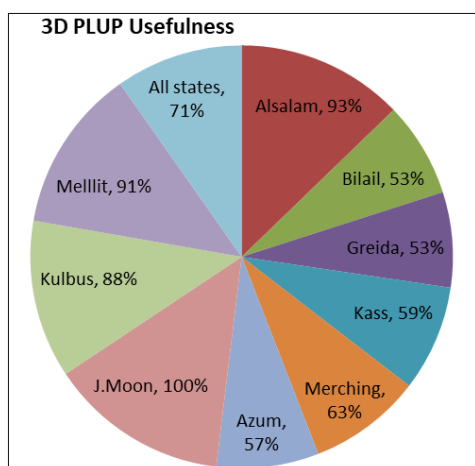**Figure 4:** 3D PLUP Model Construction Difficulty by State

Figure 5: 3D PLUP Model Usefulness in Land Management

3.1.2 Jebel Moon Locality West Darfur:

Jebel Moon is one of the two localities selected in West Darfur State for the 3D PLUP training workshop. The well-known feature in the area is the Jebel Moon hill with more than 1150 m a.s.l. The land system is mostly covered with basement, Qoz and alluvial soils along valleys and flooded areas with rainfed agriculture practices. Also the maps produced showed dense riverine vegetation (>50%) in the river beds to open savanna woodland (10-50%). Moreover, during the 3D PLUP model production, the participants raised that Hashab tree (Acacia senegal) abundant in sand soils and around Jebel Moon area and represent an important features for land management in the area, so they planned and agreed to be added to the map legend as separate feature, (Figure, 6). The mapping results also showed that sand soils are very fragile and needs to be managed with

care and avoid use of heavy agricultural machines mentioned and discussed by the community and depend on those dragged by animals like donkey plough. The participants showed great concern to the management of the sand soils around Jebel Moon because it represents the main rainfed agriculture, horticulture and gum Arabic production site. Moreover, one could detect the usefulness and flexibility of the 3D model in the land management and planning when compared the GIS map with the 3D model as in the case of Jebel Moon. The participants agreed to merge soil systems; "Sand sheets and Sand Dunes" around Jebel Moon in one soil type and added the Hashab features. Moreover, they added also the animal routes to the 3D map as its important land use system in the area (Figure.6). Furthermore, with regard to the respondent's questionnaire all participants mentioned that the 3D PLUP approach was useful in strengthening land management in the area (fig.5).

3.1.3 Rongatas_Azum Locality-Central Darfur State:

Azum locality in its head quarter Rongatas was the only 3D PLUP mapping workshop in the Central Darfur state and represents Jebel Marra area. The analog GIS map produced showed very rich classes of land use with characteristic of Jebel Marra Mountain. Accordingly, open to sparse riverine vegetation (10-50 %) has been found in most of the area with patches of dense savanna woodland (>50%) on hills and open savanna woodland (10-50%). In dry riverbeds and flooded areas horticulture used to be grown with patches of riverine vegetation and swamp. In addition to that rainfed agriculture (e.g. millet, sorghum) common practiced in river

beds and fallow lands (Figure, 9).In Azum the communities constructed two 2D PLUP instead of one 3D maps for land use and vegetation and land system. One of the usefulness of the PLUP model that the community used it to rectify and delineate the boundaries of the locality (Figure, 7).With regard to communities views upon PLUP approach all participants mentioned that it is good mechanism to deal with environmental challenged and more than 80% of them said it was easy to construct (Table 1 & Fig. 4).

3.1.4 Mellit Locality-North Darfur State:

Mellit was chosen to be the only pilot PLUP workshop in North Darfur State because of its unique location in the middle north of the state with an area of 30 X 30 km from Mellit town. For the purpose of the PLUP 3D workshop, land system and land use GIS maps had been produced (Figure 8 & 9). The land system map showed domination of Qoz soils and sand sheets in the southern parts while alluvial soils found along Wadi Mellit river bed with flood plain complex within confined valleys with scattered volcanic hills on basement areas. The land use map showed various vegetation and land use types ranging from sparse to open riverine vegetation and savanna woodland in basement and hills. Also, there are great areas of rainfed agriculture (e.g. millet and sorghum) in Qoz land and falling flood cultivation at the end of valleys and fallow lands. From the community side, more than 90% of the participants mentioned that the PLUP approach was useful in dealing with land management and strengthening (Fig. 5).
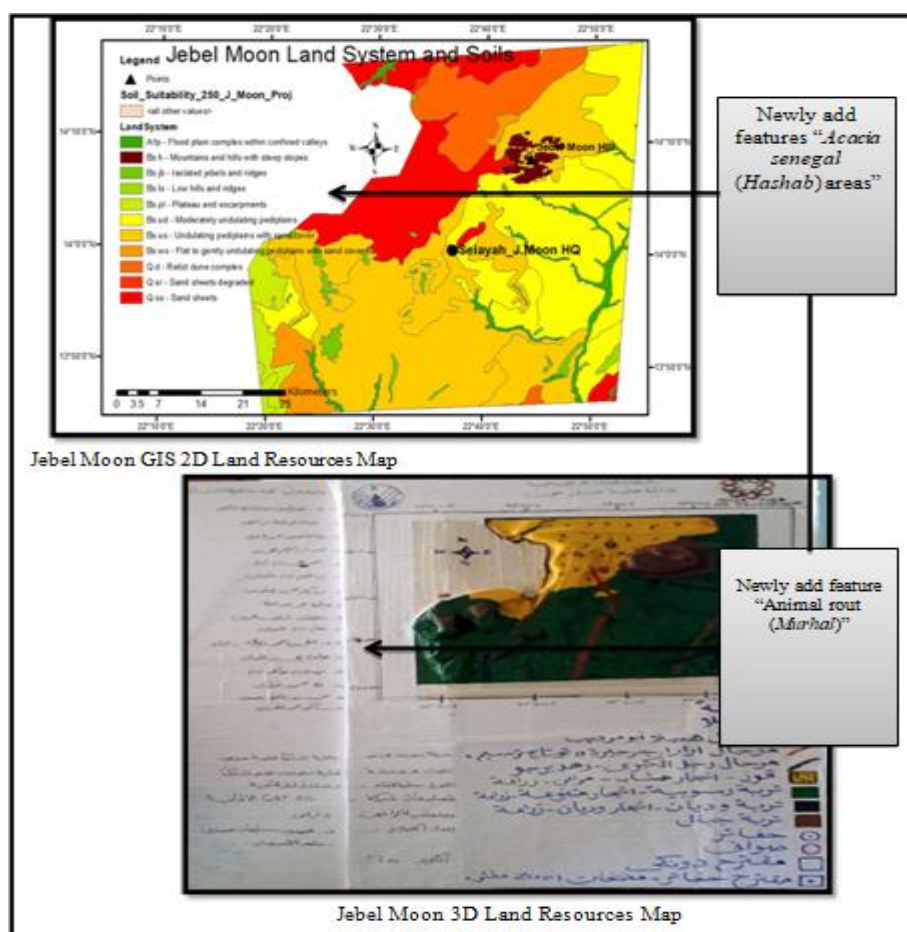

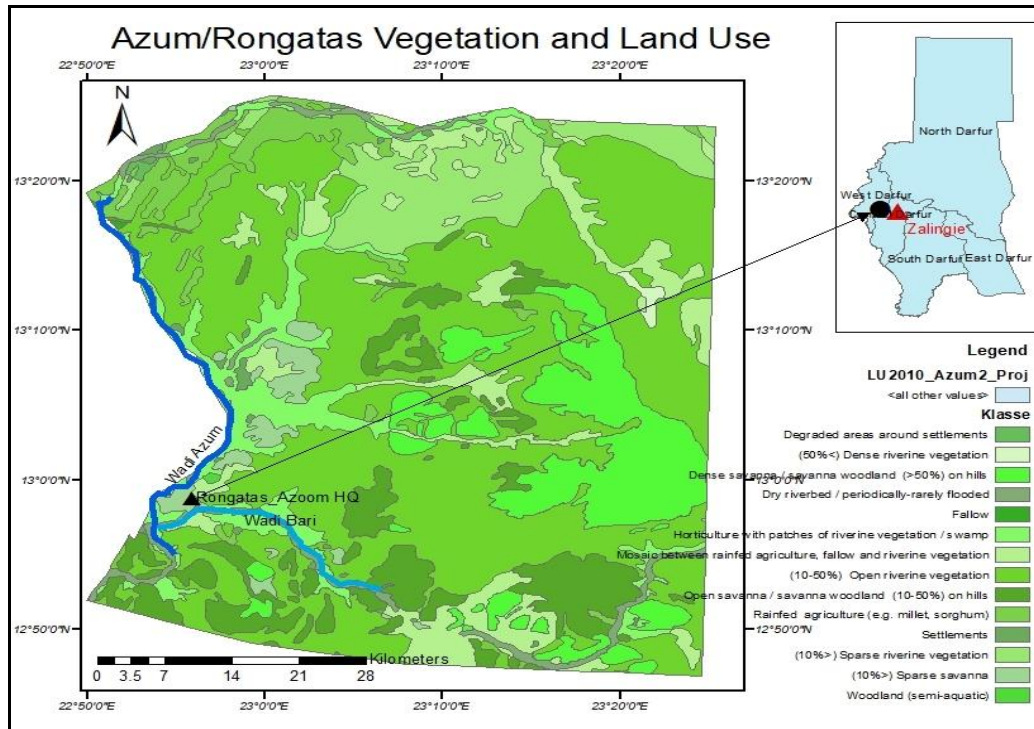**Figure 6:** Jebel Moon land Resources 2D GIS Map & PLUP 3D Model

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Figure 7: Azum (Rongatas) Vegetation and Land Use- (Source NRDB, Field GPS & Google Earth)
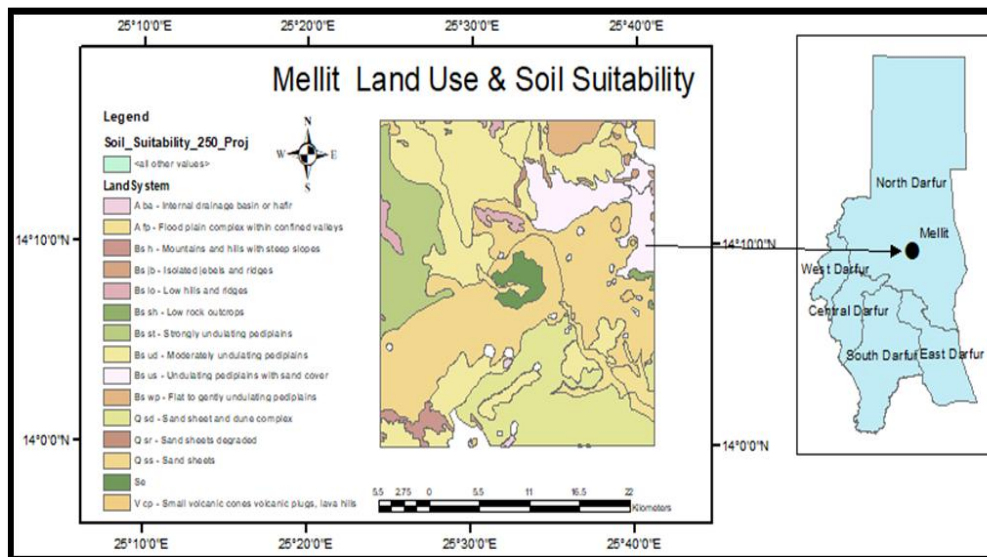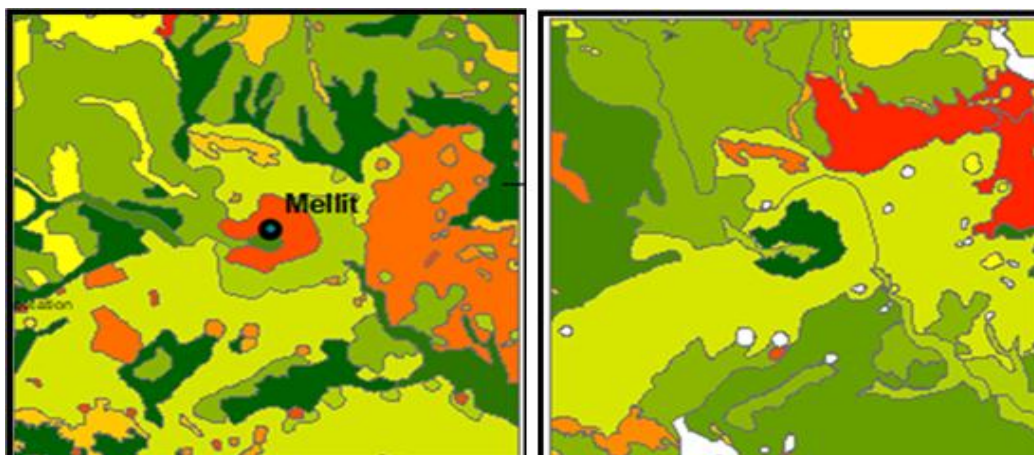

Figure 8: Millet Land Use & Land System- (Source NRDB, Field GPS & Google Earth)

(a) Mellit land System GIS Maps

(b) Mellit land System & Land Use 3D PLUP Maps
Figure 9: Millet Land Use "a" compared with Mellit Land System 3D PLUP Maps "b"

4. Conclusion & Recommendation

The study concludes that the 3D PLUP model maps were a good approach in strengthening land management especially in rural areas. Moreover, the search showed that communities have great interest in the model and willing to learn tools that deals with their challenges. Accordingly, it's highly recommended to replicate the PLUP approach in the rest of the localities in Darfur region and the country.

5. Acknowledgements

References

[1] Bourgoin, J. 2012. Sharpening the understanding of socio-ecological landscapes in participatory land-use planning. A case study in Lao PDR. ISSN: 0143-6228-Applied Geography 34: 99-110-DOI: 10.1016/j.apgeog.

[2] FAO. 2013. Food and Agriculture Organization Of The United Nations (FAO) and Water Division Working Paper 5 Participatory Land Use Planning Workshop Proceedings (PLUP). Georgetown, Guyana.

[3] Shalini P. Vajjhala. 2005. Paper for the ESRI International User Conference, Sustainable Development and Humanitarian Affairs Track, San Diego, CA.

[4] UN MDGs (United Nations Millennium Development Goals) 2015. Online Source: https://www.un.org/millenniumgoals/ Retrieved March 28, 2020.

[5] William J. Craig, Trevor M. Harris, Daniel Weiner.2002. Community participation and geographic information systems. London: Taylor and Francis.

[6] WSIS "World Summit on the Information Society (2003). "Declaration of Principles. Online source: http://www.itu.int/wsis/. Retrieved March 28, 2020.