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ENHANCING FOOD SECURITY, CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT PLANNING IN GHANA USING PARTICIPATORY THREE DIMENSIONAL MODEL MAP

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ABSTRACT

Amidst the enormous agriculture and natural resource potential of Northern Ghana, food security remains a perennial issue, more recently compounded by the recurring Volta River flooding of low-lying areas threatening livelihoods, causing damages to farmlands, properties, loss of lives and socio-economic dislocation. In an attempt to strengthen rural poor communities to take control of their lives and build resilience against such threats, many community-driven initiatives employing various participatory planning and decision making tools have been pursued over the past decade in Ghana. Most of these participatory tools also explored how collaboration among external stakeholders, local institutions and beneficiary communities could be enhanced and sustained. Currently active participation and effective collaboration have not been the best. In this regards, Participatory 3-Dimensional Modelling was presented as a tool for active participation and effective collaboration among development agencies and beneficiary communities in Ghana. The 3DM captures the vast complex landscape resources into an incredibly concise solid contour model easily understandable to the learned and the unlearned. Using the 3D map for Northern Ghana, regional stakeholders were facilitated to identify and evaluate their areas of interest on the ground in terms of their relationship to the biophysical and socio-economic attributes of the landscape. The clarity of landscape information overlaid in the 3D enhanced discussion among stakeholders and forged collaboration for greater impact, including identification of gaps in promising areas. The use of 3D in community and regional level planning for agriculture and natural resource management presents a new and more promising opportunity for more community participation and institutional collaboration towards sustainable development of Ghana.

Key words: 3-Dimensional Modelling, Food Security, Flooding, Collaboration, Participation

INTRODUCTION

The climate has changed; droughts, floods and erratic weather conditions continue to threaten the livelihoods of people in Ghana especially in the Northern sector. It is unprecedentedly washing away communities, destroying biodiversity, natural ecosystems and exacerbating food insecurity. It is therefore necessary for the cooperation and active participation of all those concerned to ensure the sustainable management of our environment and natural resources.

Since 2007 most communities within the catchment of the Volta river basin have experienced annual flooding but no permanent intervention has been put in place yet. From December 2006 to June 2007, Northern Ghana experienced long dry conditions and soon after was hit by heavy rains which resulted in floods killing 20 people and leaving 260,000 homeless (OCHA, 2007). Most of the people who were affected in the floods were poor farmers, who, after losing their

farms and other properties suffered from the aftermath of the floods, a contaminated environment and contaminated water.

Farmers within the catchments of the Volta river basin have began recording a drop in yield of 30%, a value less than the crop potential yield (CPWF, 2007). This has turned into an annual phenomenon but so far most interventions made to tackle this menace have been a post-disaster relief. Attempts to relocate farmers within the flood plains have proved futile as farmers are reluctant to move.

These among other issues and the unfavourable climatic and environmental conditions throughout the northern savannah zone are the major causes of food insecurity in the Northern Regions. Though the Northern Regions are considered as the food basket of the nation, farmer households experience a significant degree of food insecurity with food insecure periods spanning between 3 and 7 months after harvest (Quaye, 2008).

In spite of all these, Northern Ghana has enormous bio-physical land resources and socio-economic potential that, if fully tapped, would significantly improve the livelihoods of Ghanaians. Ghana has irrigation potential of 1.9 million ha of which less than 2 percent has been developed and in use (National Investment Brief, 2008). There is also an additional 1.0 million ha of valley bottoms and flood plains that could be used especially for rice cultivation if water management technologies such as bunding, leveling and puddling are employed (National Investment Brief, 2008). Rainwater harvesting using ground or land surface catchment is yet another technique that has not been explored and if adopted, can support dry season farming and reduce discharge and runoffs to rivers that eventually cause flooding.

Development actors in Ghana have pursued various initiatives over the past two decades which have significantly contributed to the substantial decline of overall poverty rate from 51.7% in 1991/92 to 28.5% in 2005/2006 and the proportion of the population living below the extreme poverty line, from 36.5% to 18.2% (UNDP, 2010). These initiatives were predominantly community-driven for food security, health planning and services and natural resources management which employ various participatory tools to involve poor and vulnerable communities in planning and decision making (CIDA, 2010; Norton, 1994; Awoosah *et al.*, 2004). Kyem (2004), successfully used GIS to resolve forest resource use related conflict in Ghana. Tschakert and Sagoe (2009) also reported on the use of mental models to communicate to communities about the drivers and the effects of climate change in Ghana.

One of the challenges in development work is the identification of effective ways to involve poor, vulnerable and disadvantaged communities in planning, management and decision making about issues that affect them (Corbert, 2009). Various participatory tools including, participatory analysis of aerial photographs, participatory video, seasonal calendars, timelines, ranking, transect walks, semi-structured interview, community mapping and modelling, dream maps and drawings, theatre, poems, songs, stakeholder analysis, have been used over the years, but participatory mapping remain the most widely used (Chambers, 2006). Among these mapping methods are ground mapping, sketch mapping, transect mapping, scale mapping, participatory 3-D modelling, GPS mapping, using aerial photographs satellite images, multimedia mapping, participatory geographic information system and internet-based mapping, with each method eliciting peculiar art of involvement and empowerment (Cobert, 2009). In the application of participatory mapping for

development works, 3-D modelling has been found to be more participatory and a lot more fun for villagers, the disadvantaged and outsiders alike (Mascarenhas and Kumar, 2001; Rambaldi and Callosa-Tar 2000, 2002 and 2005).
The box below gives the advantages of 3-D modelling over all the mapping methods (Mascarenhas and Kumar, 2001; Corbet, 2009; Chambers, 2006)

1. Effective in portraying relatively extensive and remote areas: participants appreciate better how other adjoining ecosystems affects their livelihoods.
2. Low-cost and not technology dependent
3. Power and ownership are dispersed
4. More crosschecking and triangulation
5. Locally owned because it is less mobile
6. Familiar and comfortable for many
7. It is more permanent and can store safely
8. Reusable for multiple planning exercises
9. The depth and slope aspect of the model is intuitive and understandable which give every community member the opportunity to contribute either labour or information.
10. The information on the model can easily be transposed and replicated in GIS.
11. Can accommodate overlapping layers of information (function like GIS).
12. Can be integrated with GIS and GPS technology.

In a world where climate change and environmental degradation is disproportionately threatening the livelihoods of the disadvantaged and vulnerable communities, a more appropriate tool and holistic approach needs to be explored in order to make informed decision within communities and between external stakeholders. Such a tool should be able to promote effective communication and collaboration between development agents, services, governmental institutions and communities whereby communities would have the capacity to identify, prioritize and plan development initiatives. In this way, communities would be able to develop and coordinate development initiatives, and ensure greater complementarities and synergy of development efforts. Going forward, communities can demand greater accountability from all involved in the development process.

A participatory 3-dimensional modelling is a powerful communication, research and planning tool that gives stakeholders, both literate and illiterates, rich and poor, professional and non-professional, a common platform to make informed decisions on how best to manage their environment and resources sustainably. It involves the generation of information and concepts through dialogue and collaboration by members of communities, development agencies and scientists using a physical model of the landscape of the community as a reference for discussion. This facilitates communication between all stakeholders and implementing agencies and has great potential to support sound policy and decision making process (Rambaldi and Callosa-Tarr, 2002).

Participatory 3-dimensional modelling mapping involves the location of people's spatial memories on a physical landscape model constructed using a topographic scale maps. This process always creates great excitement and self-actualisation among communities as they construct and georeference their location specific, ecological and cultural knowledge within the entire landscape. It facilitates learning, community involvement and peer-to-peer dialogue among all stakeholders with concerns related to resource access and use. It is a powerful tool when integrated with global positioning system (GPS) and GIS (Rambaldi, 2010).

In issues of climate change, food security, environmental degradation and natural resources management, application of this tool should adopt a landscape-lifescape development approach. An approach that will help people to make durable decisions on current land use that will build resilience against climate change and environmental degradation whiles taking care of future generations. Coxhead and Buenavista (1998), in their sought to sustainability, defined the landscape as 'a mosaic of interacting ecosystems with both commonalities such as soils, climate, and natural vegetation; and uniqueness, such as biodiversity, land use patterns, and socio-economic structure'. The landscape within a given geographical zone is related and affects or affected by adjoining ones. A typical example is that, the frequency and severity of flooding within a geographical zone could be appreciated more if the virtual reality of the entire or adjoining geographic land area is understood.

It is therefore acknowledged that awareness raising and mapping exercises should consider how the different components of adjoining ecosystems interact and interrelate, emphasizing on the need to maintain harmony and synergy among them. This will give participant a better perspective of how best to sustainably plan and manage their communities and initiatives.

This paper seeks to introduce Participatory 3-Dimensional model mapping as an effective planning and communication tool for food security, climate change, environmental degradation and sustainable development planning in Ghana. It also presents the construction and application of 3-dimensional model map of Northern Ghana to:

1. Raise awareness and improve understanding of important ecosystem processes and critical ecosystem linkages in landscape setting.
2. Identify potential economic initiatives and areas of interventions across landscape based on current land use and development programmes being implemented.
3. Develop sustainable mechanisms for enhancing the communication, collaboration and linkages between development organisations, governmental institutions and communities.
4. Sensitize development agencies on the use of 3-Dimentional model to identify and support communities in building resilience against the perennial flooding and drought in the northern region of Ghana, and the unprecedented degradation of the natural ecosystem.

APPLICATIONS OF PARTICIPATORY 3-DIMENSIONAL MODEL MAPPING

The geographic scope and features to overlay on a 3-D model map is determined by what it is being used for. Maps covering a wide geographical scope are less detailed and may only be appropriate for general land use planning, and identification and understanding of processes across the landscape. At the community level a more detail mapping is

essential to enable them to identify features and landmark peculiar to them. The overlay is done based on a community perspective on land use, vegetation cover, resource distribution, tenure, etc. Features that are laid out on the maps may include physical (e.g. topography, watershed, sub-watershed, location of infrastructure, roads); administrative (e.g. protected areas, buffer scopes); environmental (e.g. ecosystems, habitats); cultural (e.g. ethnicity, ancestral rights, values, customary tenure); socio-economic (e.g. settlements with associated resource-use areas, harvesting or grazing areas); territorial (e.g. conflicts, disputes, causes and effects) (Rambaldi, 2010).

3-D MODELLING MAPPING WILL SUPPORT:

1. ***Community based disaster and risk management:*** E.g. Flood hazard zoning, flood monitoring, risk prevention for flood plains and flood prone areas, and informing flood or fire fighting and disaster agencies on area estimation and extent of damage. Maceda, Gaillard, Stasiak, Masson & Bebre (2009) used 3-D model at a scale of 1:400 in Divinubo, a small island located off the island of Samar on the Pacific edge of Philippines to help the community reduce vulnerabilities and raise capacities to withstand natural and other hazards. At the end of the process, the community identified eight assets crucial to their everyday life: the community multi-purpose hall and tourist cottages, the village houses, fishing, subsistence farming, cash crop agriculture, tourism activities, retail shops, transportation and boats. The community agreed on agricultural field that could be protected with the financial support of the community members. They also identified sites safe from major hazards and engendered discussions on their tenure. A 3-D model at a scale of 1:5000 is detailed enough to support community based vulnerability and risk assessment and flood hazard mapping. This is a very good tool that can support disaster and risk management of communities within the catchment of the Volta Rivers of Ghana and general land use planning at the community level. A scale of 1: 20,000 and above can be used for risk reduction planning across large geographic area (Rambaldi, 2010).
2. ***Collaborative Planning and Research:*** Several reports by People's Participatory GIS practitioners proves that using 3D model as a reference for discussion and planning facilitates mental handling of spatial knowledge. E.g. At the regional planning level, it can support the identification of potential lowlands or high lands for development, assessment of environmental impacts of projects and policies and stakeholder dialogue on how their activities influence each other across the landscape. At the community level 3-D model can help community members in land use planning, resource access and utilization, identification of small water impounding sites, rainwater harvesting for irrigation purposes and being informed on how to effectively manage water on their farms. Escobar et *al.* (2003) used a 1:3,000 scale Participatory 3D Model of the Potrerillo sub-watershed, Microcuenca de Pescador, Cauca, Colombia in 2001 to help scientists communicate better with farmers. Until it was done scientists and farmers had different spatial perceptions of natural resources, research had not been very successful, adoption of new technologies was very low because the information was not considered relevant by farmers.
3. ***Collaborative protected area management:*** Rambaldi (2010) lists numerous ways in which 3D has been used in other parts of the world in managing protected areas which can equally be employed in Ghana. Rambaldi *et al.* (2005) constructed 3-D model of Ovalau Island, Lomaviti Province, Fiji Islands, for developing resource management, tangible and intangible cultural heritage preservation and development plans. Immediately after the completion participants were able to learn names of places they don't use anymore. Two years later Ovalau islanders were able to develop an island-wide natural- and cultural resource use management plan which was

followed by 3 district management plans. They have been able to establish taboo (protected) marine areas within fishing grounds of 3 districts comprising 16 villages. Nearby island partially included on the 3D model have also set up a protected area among its 10 villages. Areas of intervention in Ghana may include involving communities in developing resource-use and management plans including zoning and boundary delineation; conducting preliminary collaborative research on distribution of species; monitoring changes in land use, vegetation cover, human settlement, infrastructure development and other features; substantiating public hearings and planning workshops; supporting students' learning about local geography and resource use; raising awareness about, for example, the hydraulics of watersheds (e.g. upstream-erosion / downstream sedimentation effects); and conducting a preliminary census of protected area occupants.

4. ***People Empowerment:*** The clarity of landscape resource information at the hands of the community will transform them from passive to active participants in land use policy decisions and landscape initiatives to ultimately take control of their lives.
5. ***Discovery learning:*** It helps discover resources which hitherto were not known to external stakeholders and some community members. It provides a birds-eye view which help participants understand how the landscape interrelates with their livelihoods.
6. ***Improving communication***: It is a powerful tool that enables disadvantaged and illiterate persons to effectively participate in planning. It eases communication and overcomes language barriers.
7. ***Traditional knowledge and intellectual property right:*** A detailed or small scale map allows knowledge holders to accurately locate their spatial knowledge. E.g. Knowledge holders of indigenous and endangered medicinal plant species who for some reasons, can't move for longer distances, can pass on their species and location specific knowledge to younger generation using the 3-D map. They can also help map out past flooding incidences to aid disaster risk management. A 3-D model of the Mau Complex, Nakuru and Narok Districts, Kenya, was constructed in 2006 for the Ogiek People to regain their cultural identity and lost ancestral territories. Elders populated the model with their memories dating back to 1925 and reconstructed the landscape as it was at that time. The map raised awareness on the critical status of the entire Mau Complex in terms of depleted forest cover and affected watershed functions. The mapping process stimulated community cohesion and surfaced lost memories. At the end of the process, elders got a more holistic understanding of their social, cultural and bio-physical environments (Rambaldi *et al.,* 2007).
8. ***Monitoring and Evaluation:*** It is very useful when integrated with GPS and GIS in monitoring deforestation and desertification over a period of time.

3-Dimensional Model Map of Northern Ghana

A 1:250,000 scale 3-D model of Northern Ghana with contour interval of 50m was constructed based on the methodology described by Rambaldi (2010). The building of the model employed the use of chip boards, white paper glue, poster and oil paint, brush, topographic map, pins, yarns, carbon paper, masking/packaging tapes, plywood, nails, wood, scissors, markers, cutters and pencils. Due to the scale of the map, the contour lines of encampments and mountains appeared clustered. Therefore individual lines were isolated using GIS. This was done for each line before printing, tracing and cutting (Figure 1).

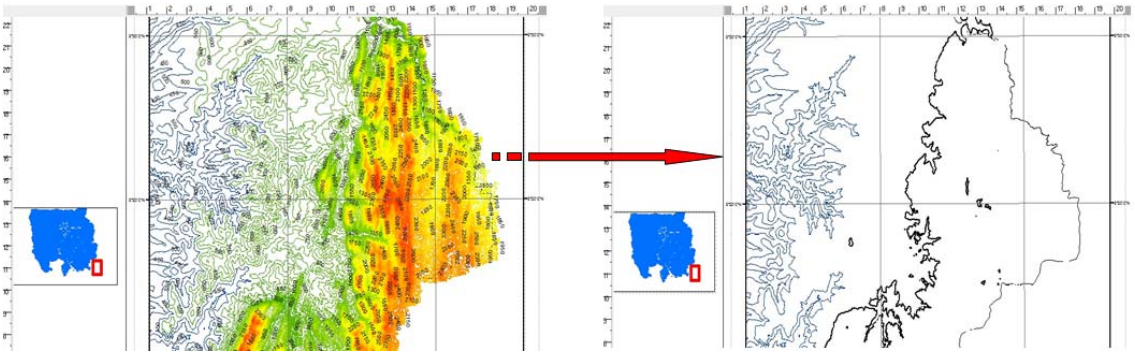

Figure 1: Isolation of contour lines

The people who built the 3D model were National Service Personnel, staff of Ministry of Agriculture, Northern Region and VSO volunteers. After the construction they all supported the overlay of regional boundaries and the major road networks. The map has a dimension of 1.9 x 1.5 m covering an area of approximately 11,244,000ha. The vertical exaggeration is x5. The lowest elevation is 250 m above sea level (a.s.l) and the highest is 3000 m a.s.l. Figure 2 shows the images of the uncompleted and completed model map.

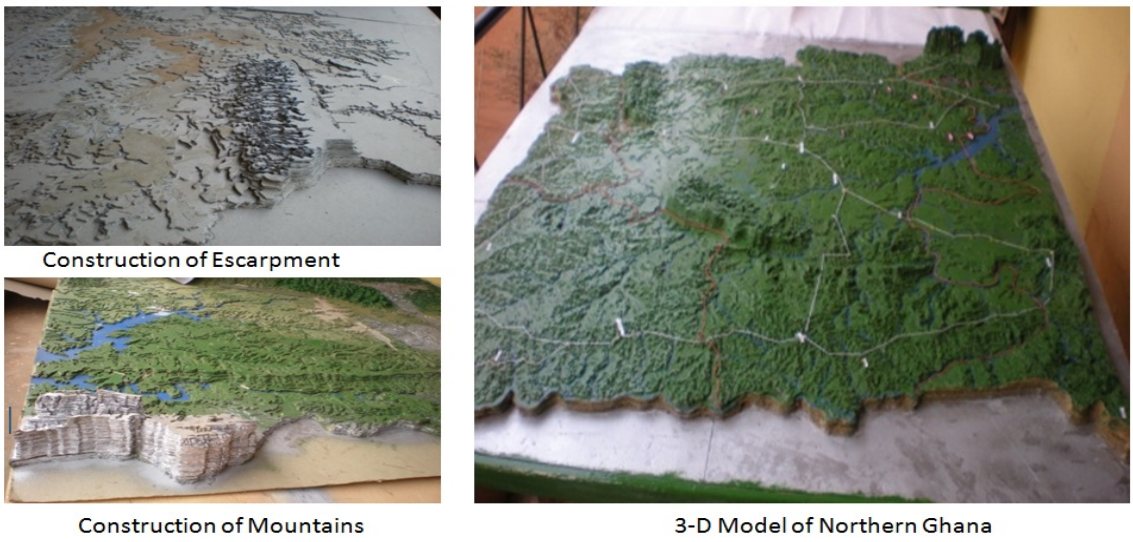

Figure 2: Three Dimensional model map of Northern Ghana (Scale 1: 250,000)

CURRENT USE OF THE MAP

After the completion of the map, it was presented to both regional and district staff of Ministry of Food and Agriculture (MoFA) in the Northern Region, MoFA collaborators [Japan International Cooperation Agency-JICA, German International Cooperation -GIZ, Engineers Without Borders -EWB, Agence Française de Developpement –AFD, Northern Rural Growth Project), ProNet (NGO in Upper West Region of Ghana), Voluntary Service Overseas- VSO staff and volunteers, Environmental Protection Agency, National Disaster Management Organisation, United Nations Development Programme- UNDP and Mennonite Economic Development Association which was on an exploratory visit to Northern Ghana to identify suitable avenues to support food security in the region.

Figure 3: Stakeholder Dialogue

Figure 4: Landmarks of Selected Lowlands for the Rice Sector Support Project

The map is primarily being use by MoFA staff working at the regional office as coordinators of all agricultural activities being implemented by government and the main point of contact for other institutional collaboration.

Representatives of some collaborating institutions that influence food security in the Northern region were invited for a stakeholder meeting (Fig. 3 & 4). They were briefed on the 3-D map and its potential uses. All the stakeholders were asked to locate their activities and that of their partner organizations on the map. After the localization of activities across the landscape, the stakeholders were asked to discuss these questions:

1. What are your goals?
2. How do your activities interrelate with the landscape?
3. How are you related with activities of other institutions?
4. How can you use the 3-D model to support development in Ghana?

After the discussions, all the stakeholders got a general understanding of the landscape and how it interrelates with their programmes. The whole activity helped to identify the interrelationships between projects and contributed to building collaboration between stakeholders whose activities are interrelated. They also identified where most development programmes are concentrated and created an avenue to identify other areas that need interventions. It also informed all stakeholders on the appropriate interventions to take on land areas where there is high depletion of natural resources as a result of the current land use pattern. For example it was noted that there is high deforestation rate in West Gonja District as a result of their farming practices. Therefore recommendations were made on the possible development initiatives that can help recover the degraded land and forest, and also provide alternative for the current practice. Another revelation was that, most of the organizations have farmer group formation and capacity building as part of their objectives. Therefore organizations operating within the same geographical location agreed to pull resources together to strengthen existing farmer groups in order to synergize output.

Other stakeholders also used the map to identify and estimate lowlands they can put into rice cultivation as part of their ongoing programmes. The MoFA staff present at the meeting thought of using the 3-Dimensional model to estimate the extent and damage of future flood to cropping areas using geo-referenced locations of these crops within polygon

following the 3-D contour lines. Other economic initiatives were identified especially at locations where there were less resource allocation and development initiatives.

Some other stakeholders also saw it as a tool to assess the environmental impacts of projects and activities across the landscape.

Participants responded to the fourth question and remarked that most development organizations enter into communities without a detail idea about what other organizations are doing in the community and the overall development plan or agenda of the community. This normally ends up in the duplication and cancellation of efforts. Where other development initiatives are known, it always happens that the different organizations operating on the ground have different project implementation plans that may contradict. This always confuses poor resource farmers which consequently hinders them to fully adopt technology or models that are introduced to them. They also observed that there are no complete data sources on resources available in communities where external agents can factor in their programme planning, therefore making them start from the scratch all the time.

This gave them the impetus to recommend 3-D model as a tool to empower regions, districts and communities so that all resources and medium to long term development plans can be featured. In this way external organizations can provide support that is within the framework of the overall agenda of the community, district or region. It is hoped that this will give them control over development, in both the ability to influence decisions and managing development directly.
The stakeholders also commented that most of the communities they work with got flooded resulting in their failure to meet targets that would have ensured all year round food security among their beneficiaries. The 3DM will be the ultimate tool for them to involve the communities in planning as its details allow for a purposeful discussion that is easily understood by all.

They explicitly expressed how the map can be used to empower communities in development planning especially to curtail the impact of the perennial flooding incidences and long drought periods in the region.
The map has currently become a planning tool where different themes are featured depending on the issues under discussion.

CONCLUSION

This paper presented Participatory 3-Dimensional model mapping as a planning and communication tool for food security, climate change, environmental degradation and sustainable development planning in Ghana.

When presented with the 3D map, multidisciplinary and inter-institutional stakeholders immediately identified their areas of interest such as their program areas communities across the landscape. This geographic location readily enabled them to relate to agro-ecological, and socio-economic attributes of the land that concerns them and discussed with other institutions on commonalities of their programs, and started forging areas of collaboration.

Gaps were also identified for potential areas that remain largely untouched. For example: the huge irrigable lands for example and the potential water based on the nearest water resources were also identified. Also, the flooding hazards

were particularly discussed especially in relation to crop losses, damages to properties and loss of lives, community resettlement, and disaster management.

Other issues like accessibility and roads networks, human settlements, mining, livestock areas, crop zoning and natural reserves were discussed as understanding of the landscape attributes are more clearly presented in the 3D model.
As Ghana accelerates in economic growth, there are high implications for deforestation, agricultural practices, and natural resource management. Therefore development practitioners view 3DM as a tool to empower communities who are the primary users of natural resources, and whose decisions are critical in the sustainable management and planning of these resources.

It is envisaged that the 3-D model will help solve the complex sustainable agriculture and natural resource problems involving a wide range of stakeholders in the Northern sector of Ghana who may have conflicting and/or complementary interests. The use of 3-D model for all planning activities especially in local communities is imperative in ensuring sustainable development in Ghana.

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