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Multi-objective space analysis of Ghana's emerging Northwest Gold Province

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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

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ABSTRACT

The vision of the African Union (AU), coordinated by the United Nations Economic Commission for Africa, considers the development of mineral resources as a mechanism for addressing economic diversification, industrialisation and integrated rural development. However, this vision is resisted by ordinary people of the African community. The resistance is backed with emerging land use issues, driven partly by perceived threats of mining sector activities that lead to changes in livelihood activities and environmental resources in local space. In spite of the global significance of these conflicts, development of efficient tools tailored towards mediating possible peaceful co-existence between large-scale mining companies and other land use interest groups in the local landscape remains inadequate. This study, therefore, analyses the spatial outlooks of resistance against large-scale mineral resource development in Ghana. The outcome of these analyses would enhance existing mediatory mechanisms for managing large-scale mining land use conflicts in developing countries.

The study attempted a multi-objective space analysis for mediating peaceful co-existence between mining, agricultural and non-agricultural livelihoods, and other land use interest groups in the landscape. The methods used in this study provide room for creative flexible solutions and collaboration among stakeholders. This originates from two schools of thought: Strategic Environmental Assessment, and Collaborative Planning. Geographic Information Systems, remote sensing, spatial and economic base analysis are employed to develop models of the physical and socioeconomic factors of the landscape. For this purpose, a case study is conducted in the emerging north-west gold province of Ghana to demonstrate the strategy, and to provide empirical testimony for consideration and discussions. The study hypothesises that resistance against large-scale mining sector, in areas with no history of mining, is a function of perceived and real threats of mining-induced displacement of communities.

The study finds that a minimum of 8,916 ha and a maximum of 32,353 ha of cultivable lands and pastures would be displaced by exploration and mining activities across the districts studied. This looming phenomenon will affect a minimum of 630 households in crop farming. The evidence also suggests that a minimum village area potentially displaced by exploration and mining leases is 90 ha, and the maximum is 4,577 ha. Analysis of potential displacement of livelihood structures of women in affected local communities show that Shea tree and related industries are significant

non-agricultural rural economic activities in the area. Thus, a minimum of 109 and maximum of 5,538 Shea trees would be displaced, inflicting penury on women at a minimum of 15 kg of Shea headload in potentially affected communities. At the district level, a minimum of 22460 Shea trees would be displaced, which affects at least 7 kg of Shea headload per woman. These results show the disparities of impacts of mineral resource development at the host community and district levels. It supports the hypothesis that impacts of the mining sector activities on affected communities would have a cumulative effect on the inter-connected livelihood systems of the entire host district. This cumulative effect is a precursor of wider resistance since rural production systems provide the resource base of urbanised areas.

Analysing the relationships between mining and environmental resources, the results indicated that mining concessions are granted in areas that are within a minimum erosivity index of 42 mm. Thus, within active mine operation sites, a minimum of 225 trees and 24,827 kg of forage would be removed; and within an entire concession, a minimum of 2,432 trees and 229,020 kg of grass cover would be displaced. As a result, a minimum of 2,632 households would be displaced from the use of environmental resources in each district studied. These findings illuminate the links between mining sector activities, future land degradation and sustainability issues in the area. Further, investigations of the relationships between mining and water stress phenomenon show that emerging water use by the mining sector would increase water stress in the area. This would account for a minimum of eight households potentially ruined from access to potable water for both drinking and other domestic uses.

The evidence also provides insights over a potential conflict between Ghana and neighbouring communities in Burkina Faso due to impending water stress from mining tenements to the Volta drainage basin in the northwest of Ghana. An Iso-aridity map developed in this study also showed that districts hosting large areas of mining concessions are arid and vulnerable to desertification.

Assessing the physical suitability of local space for enhancing options for sustainable resettlement of future mining-induced displaced communities showed generally unsuitable patterns. The results indicated large expanse of waterlogged areas and settlements. These patterns are antagonistic to agricultural production and sustainable livelihoods. Previously vegetated areas would be cleared to make way for settlements and farmlands, increasing the effects of waterlogging, erosion and flooding risks. Since exploration and mining activities would further displace vegetative cover, thereby, increasing the number of shear stress and length of erosional land degradation, the observed patterns limit opportunities for sustainable resettlement and productivity. These trends are illustrated with an Iso-aridity map of the area, which has been developed in this study.

Albeit, findings of the study may be used to improve the level of communication between the mining industry, local communities and governments. The findings would enhance initiatives for removing tensions over livelihood risks and uncertainties at both village and district levels. Besides, the results can fill the knowledge and power gaps between local communities, companies, governments and civil society groups concerned with the spatial extents of project approvals and environmental degradation. Overall, the study provides baseline knowledge that would facilitate informed decision making, efficient mineral resource development and water resource management. Further, the results of this study can be used as benchmark indicators for monitoring and evaluation; validating the Environmental Impact Statements (EISs) and Social Impact Assessments (SIAs) of mining companies in the study area. Most importantly, the findings may be used for evidence-based establishment of mechanisms for an efficient management of shared water resources between neighbouring governments along the Volta basin in West Africa. This is in line with the post-2015 development agenda of the African Union.

The findings of this study would be useful for resettlement and post-mine land reclamation planning in the region. The results also provide comprehensive geospatial data that is usually lacking, especially at sub-national levels in developing countries. In particular, the geospatial data could augment existing data for efficient spatial planning by the local government sector. The results would also be useful for flood hazards management, mitigation and rural land use planning. Furthermore, the African Union has declared its commitment to support member countries for an optimum management of natural resources without compromising the livelihood and food security of communities. Thus, these findings could be used to supplement existing data for designing a holistic environmental management plan in the study region, for enhancing the industrialisation and economic growth goals of the African Union, in particular.

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DEDICATION

I dedicate the scholarship demonstrated in this PhD thesis to my late fathers: Moalim Moomen Alhassan (Moomen 'Massala'), Alhaji Salih Alhassan ('Liman Salia'), their grandparents; 'Karima' Mahama 'Saglaa' and Liman Abdul-Kadir; and the entire family; both late and living. I further dedicate this scholarly work to the delight, honour and loving memory of my late uncle Imam Khalid Bin Salim ('Nnabaa Liman'). Finally, it is my sincere honour to dedicate this thesis to the entire 'Jujeidayiri', a well distinguished family of scholars in Wa, Upper West Region of Ghana.

LIST OF PUBLICATIONS

This PhD thesis by publication comprises of one single author and three first author peer-reviewed publications; one first author paper in press; and one first author full-length conference paper. This gives a total of five peer-reviewed journal papers and one conference paper, thus, six first author peer-reviewed publications. These articles have been published in the following journals and conference proceedings. Please, refer to Appendix A for copyrights clearance, Appendix B for signed declarations for author contributions, and Appendix C for proof of a peer-reviewed conference paper, respectively.

1. Moomen, A. W., and A. Dewan. 2015. "Mining, agricultural space and land use conflicts: The role of local government." Agro-Geoinformatics (Agro-geoinformatics), 2015 Fourth International Conference on, 20-24 July 2015. DOI: 10.1109/Agro-Geoinformatics.2015.7248103. IEEE
2. Moomen, A.W. 2015. "Quantifying Potential Socioeconomic Displacements and Land-use Conflicts in Prospective Mining Villages in Ghana." WSEAS Transactions on Environment and Development, Volume 11, 2015, Art. #35, pp. 325-342
3. Moomen, Abdul–Wadood, and A. Dewan. 2016. "Analysis of spatial interactions between the Shea industry and mining sector activities in the emerging north-west gold province of Ghana." Resources Policy 48:104-111. DOI: http://dx.doi.org/10.1016/j.resourpol.2016.03.001.
4. Moomen, A.W., and A. Dewan. 2016. "Assessing the spatial relationships between mining and land degradation: evidence from Ghana." International Journal of Mining, Reclamation and Environment. In Press. http://dx.doi.org/10.1080/17480930.2016.1188253
5. Moomen, A.W., and A. Dewan. 2016. "Investigating potential mining induced water stress in Ghana's north-west gold province." The Extractive Industries and Society. DOI: 10.1016/j.exis.2016.04.002
6. Moomen, A-W., Dewan A, Corner R. 2016. "Landscape Assessment for Sustainable Resettlement of Potentially Displaced Communities in the emerging Ghana's Northwest Gold Province." Journal of Cleaner Production. DOI: 10.1016/j.jclepro.2016.06.004

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CHAPTER 1 Introduction

1.1 Background

When rural resources are exploited sustainably, the beneficiations may be wide spreading and mutual between local communities, companies, governments and other stakeholder groups (McPhail 2010; Hanlin 2011). However, Pegg (2006) argues that isolated rural communities that host mining projects lose more than the perceived benefits. Therefore, the looming development of mineral resources in developing countries (Shaw 2015) has considerable implications; a new competition for land-use, water-use, economic livelihood and other ecosystem services. Thus, resistance against large-scale mineral resource exploration and extraction has been a global topical issue for the mining industry, more so in resource-rich developing countries than in developed countries (Hodge 2014). Hence, industry players and other stakeholders, such as the emerging social movements against mining, universally recognize the need to identify and address the potential risks, opportunities and limitations associated with mineral resource development prior to project approval (Joyce and Thomson 2000; Bebbington et al. 2008). In effect, Buckles and Rusnak (1999) indicate that conflicts are better managed when the underlying causes are analysed, and properly understood.

To this end, Twerefou (2009); and Hodge (2014) have identified four major areas of company-community conflicts in mining regions. These are: distribution of royalties, land use, resettlement, and small-scale mining. However, Hintjens (2000) discovers that land use is the overarching of all company-community conflicts. In his book *Mining for Sustainable Development in Tanzania*, Kulindwa (2003) imputes mining related land use conflicts to the lack of planning and co-ordination at the governments level and misconceptions at the local levels. Thus, Jenkins (2004) has identified displacement and resettlement as fundamental to land-use conflicts between the mining industry and local communities.

Hence, land use conflicts are recognised, in this research, as a function of displacement of communities for exploration and mining activities. Displacement could be physical or economic. Physical displacement involves relocation of settlements and means of livelihood from their current occupancy (Cernea 2000). It also involves reductions or a loss of the quality and quantity of environmental resources such as water, and ecosystem services. Economic displacement entails the imposed or induced loss of assets and income of the affected local communities

(Cernea 2000; Downing 2002). The study hypothesises that resistance against large-scale mining sector is a function of perceived and real displacement of local communities by the mining sector activities (Thomson and Joyce 1997).

1.2 Literature review

1.2.1 Towards land use conflicts in mining regions

There are several factors influencing land use conflicts between the mining industry and local communities, and they vary from one geographical location to another. In spite of the global importance of these conflicts, analysis of the basic causes, as perceived by the main actors, is limited to narratives and popular thoughts (Jenkins 2004; Hodge 2014). Anyhow, the dynamics of human society, both in size and in complexity, determines its needs and the possible ways to provide these needs. Thus, land resources and land related activities are significant in providing the needs of society for economic and physical development in both developed and developing countries.

For case in point, land is the primary resource upon which the majority of rural communities depend for both agricultural and non-agricultural livelihoods. Rural areas harbour the natural resources of most countries including large land sizes, fertile soils, vegetation, wildlife, and mineral deposits. However, large tracts of lands of communities are often awarded for mineral resource exploration and mining, which endangers provisioning of the basic needs of local communities. As Cernea (2003b) has found, the immediate needs and land use interests of rural communities in developing countries are grain and meat, either by the ploughing of land or by hunting, gathering and caring of economic trees. These variations over the recognition, needs, allocations and the use of rural resources pose resistance and conflicts in resource-rich countries (Roy 2007).

Local communities view exploration activities on their land with lots of thoughts and uncertainties. Thus, the perspective of communities about mineral resource development is often curious and conclusive. Although industry experiences suggest that exploration does not necessarily lead to mining (Singer and Kouda 1999), for local communities, exploration activities are precursors of possible mining. Once exploration leases are granted, land use and occupancy by communities become limited, starting the processes of psychological displacement. Nonetheless, community resistance against mineral resource development partly results from past negative experiences of economic hardships, spatial structural imbalance, environmental and social configurations and partly from perceived impacts of mining activities (Joyce and Thomson 2000; Akabzaa and Darimani 2001). These uncertainties and anxieties sometimes lead to violent negotiations for land use rights between local communities and companies (Hilson 2004).

Gray and Kevane (2001) and the Human Rights Clinic (2010) suggest that a weakened customary property rights for the allocation of community lands for exploration and mining is a major cause of land use conflicts across mining regions. Land rights refer to the right to use, control, and transfer a parcel of land, occupy, enjoy and use land and its resources. They also include the right to restrict or exclude others from selling, purchasing, granting or loaning, inheriting and bequeathing, developing, renting or subletting, and benefitting from improved land values or rental income (FAO 2002). Though in rural areas of developing countries land certificates are not the norm in land acquisition, land rights are recognised traditionally and communally among community members.

However, in mineral resource-rich developing countries, whilst customary or indigenous lands are recognised, the rights of use and occupancy of mineral resource endowed lands are a vested prerogative of the State (Lange 2008; Resosudarmo et al. 2009). Examples include Ghana, Tanzania, Mexico, Indonesia and Republic of South Africa. For this reason, Peters (2004, 2002) argues that land reform programs that have opened customary lands to foreign investments are the causes of exclusion and the consequent deepened social divisions of underprivileged groups in traditional African societies.

Further, Wunder (2005) submits that political and social realities of mineral resource extraction often exacerbate land use conflicts between native communities and mining companies. For instance, Tsuma (2010) and Hilson (2004) argue that the Structural Adjustment Program (SAP) introduced by the World Bank in the 1980s, brought with it mining sector policy reforms in developing countries. The SAP limited governments from the management and ownership of state mining companies. Thus, concessions of state mining companies were transferred, together with lands of local communities, to foreign investors. This policy led to the introduction of land privatisation that displaced communities from farming to non-farm based activities, leaving many poor people without a source of livelihood (Chimhowu and Woodhouse 2006).

Besides, the Poverty Reduction Strategy Papers (PRSPs) in most developing countries prioritized progress of agricultural productivity so as to expand the food baskets of the rural poor (Yaro 2011). Therefore, surface mining methods mostly used in these countries worsened the incipient competitions and conflicts over land use. The burden lies on governments and companies to develop synergistic approaches beyond the Corporate Social Responsibility (CSR) of the mining industry.

Moreover, land use conflicts in mining regions could be attributed to the failure of exploration and mining companies, and governments to properly delineate local communities under concessions. For instance, Jenkins (2004) analysed the reports of 16 globally operating mining companies and concluded that companies are disinclined to explicitly give meaning to 'community' and delineate the boundaries of communities on whose land they operate. Companies perceive affected villages in isolation and usually limit negotiation efforts to the immediate vicinity of their operations.

On the contrary, particularly in Sub-Saharan Africa, rural households are linked by systems of social and cultural networks of rights and obligations to people (Ellis 2000). For instance, Cousins (2009) explains that communities in African societies have multiple and overlapping identities that cannot just be scaled down to a singular unit of settlement. Key elements in these relations include access to land that defines the livelihood and identity of communities. Thus, assets issues concerning one village affect a chain of others. Nonetheless, there is no evidence of commitment of companies to delineate and acknowledge these networks of local communities. Rather, companies narrow the definition of local communities to their immediate hosts and, therefore, do not extend CSR courtesies and protocols to community networks.

1.2.2 Mechanisms for mining-related conflicts management

Rural development experts indicate that rural problems are diverse and multi-faceted and should, therefore, be addressed with holistic approaches (Bebbington et al. 2008; Yaro 2011). Since mineral resource extraction is a rural phenomenon (Hilson 2002), understanding and managing related issues require a holistic approach. However, Obara and Jenkins (2006) propose that land use disputes in mining regions should be approached with a better understanding of the individual causes in isolation rather than using a holistic approach. Thus, governments and companies need to understand the complex web of the structures of communities so that suitably tailored conflict management strategies may be developed. This involves numerous activities to be orchestrated carefully for sustainable futures. Hence, mechanisms for managing mining-related conflicts include: legislative policies, regulatory principles and customary tools on the part of governments and corporate financiers; and social license to operate (SLO) on the part of the mining industry. The scientific community employs economic and environmental analysis.

1.2.2.1 Legislative policies, regulatory principles, and customary instruments

State legislative instruments and policy frameworks that regulate land use and rights for mineral resource extraction often contain provisions for addressing the concerns of aggrieved communities. Although these statutory clauses outline and define land tenure systems and conflict resolution processes, aggrieved communities and individuals are often required to back their claims with tangible evidence. However, due to capacity limitations of individuals and communities to show evidence of impact risks and displacement, governments and companies in developing countries approve projects in advance despite community censure. Besides, these mechanisms are often defined by the terms and conditions of international trade binding in most developing countries (Shaw 2015; Humphreys 2005). Therefore, state governments weakly apply laws that would protect land use interests of communities from mining sector dislocation. Hence, communities often resort to strained means of expressing their sentiments.

Nonetheless, state governments develop regulatory standards and legal rules in the form of permits and land use rights in order to manage conflicts in mining provinces. Examples include *Canada's National Parks Act*, which permits metal mining within national parks under certain circumstances (Carey 2008); The *Resources Legislation (Balance, Certainty and Efficiency) Bill 2011*, and the *Strategic Cropping Land Act 2011*, of the Queensland government (Australia); The Surface Mining Control and Reclamation Act of 1977 (SMCRA), the *Endangered Species Act* and the *Clean Water Act* in the USA (Craynon et al. 2015). However, in developing countries regulatory guidelines are ambiguous and vain, thereby, worsening land use conflicts situations. For instance, whereas policies governing mining activities prohibit excavation on conservation and agricultural areas, policy reforms support concession holding within forest lands in Indonesia and Ghana (Hilson and Nyame 2006; Cronin and Pandya 2009). As a result, state regulatory oversights of the activities of companies are deemed unreliable tools for addressing local concerns. Thus, as mining expands over the approval period, the economic futures and livelihood of communities become uncertain and anxieties are expressed through resistance.

Corporate Financiers, like the International Finance Corporation (IFC) of the World Bank, and the African Development Bank (AfDB), have set regulatory standards such as the ‘‘Equator Principles’’ (Equator Principles 2013). These standards are binding on all client extractive companies towards mitigating company-community conflicts. However, the principles have been unsuccessful in developing countries (Slack 2012) largely due to the nature of growing mining sector projects and the perceived social and environmental impacts of these projects on local communities (Hodge 2014). A rising number of social movements, and international agencies such as non-governmental organisations (NGOs), and the International Labour Organisation (ILO), lead initiatives to safeguard the land rights of local communities in mining regions. These movements sensitize communities on issues including: (i) rights to mitigation of adverse effects; (ii) rights to compensation of equivalent value; and (iii) rights to freely dispose of wealth and natural resources (International Labour Organisation 2013; FAO 2002). These initiatives give rise to the resilient contention of communities for the real application of corporate regulations on mining sector activities, which are often dysfunctional.

Instruments proffered by governments and corporate financiers accentuate community consultations prior to authorising exploration or extraction. However, the numbers and magnitude of resistance against mining projects are increasing (Hodge 2014). Thus, governments rather resort to enforcing legal codes. Notably, in developing countries, access to rural resource base is mediated by the culture and values of the people rather than state laws and regulatory policies (Yaro 2006a; Ellis 2000). In these communities, law is repressive and solidarity is mechanical, precluding the application of legal codes for managing mining-related conflicts.

1.2.2.2 Industry approaches

One of the major initiatives of the mining industry towards conflicts management is the introduction of Corporate Social Responsibility (CSR). Through

CSR, the industry pursues its commitments to addressing socioeconomic and environmental concerns of local communities. In addition to the CSR, other programs evolving from the mining industry, specifically, aimed at identifying the main challenges and possible strategies for managing company-community issues include: The Global Reporting Initiative (GRI), and the Extractive Industries Review (EIR). Others are the Mining, Minerals and Sustainable Development (MMSD) project commissioned by the International Institute of Environment and Development (IIED) and the World Business Council for Sustainable Development (WBCSD) (Owen and Kemp 2013; Roe and Samuel 2007). Inspite of all these initiatives, companies have not been efficient in addressing environmental and social issues beyond their profit ambitions. This gap is evident in the rising numbers of company-community conflicts in developing countries over the past three decades (Hodge 2014). Hence, many have questioned the commitment of mining industries towards managing community concerns in tandem with its interests in developing countries (Fonseca 2010; Wasylycia-Leis, Fitzpatrick and Fonseca 2014; Slack 2012).

As a result, the most recent mechanism introduced by the mining industry towards mitigating resistance is the 'Social License to Operate' (SLO). This mechanism connotes a general social acceptance and the consent of communities of a company's activities (Boutilier, Black and Thomson 2012). However, the basis upon which communities grant companies an SLO is elusive. Thus, Joyce and Thomson (2000) suggest that the best way to obtain SLO is an early engagement with communities, clear disclosure of information, and development of conflict resolution mechanisms. Conversely, Prno and Slocombe (2012) question, among others, the capacity of communities to analyse and understand their environmental and socioeconomic conditions and be able to link that with the potential impacts of the industry before granting an SLO.

The current deportment of the SLO makes little provision for the empowerment of local communities for free sharing of basic knowledge upon which an SLO can be obtained. There are instances, where communities initially accepted mining projects but later bounced on companies with disagreements, on the basis of unsustainable arrangements and lack of intuitive understanding of a project's impacts (Szablowski 2002; Boutilier, Black and Thomson 2012). Thus, inspite of the introduction of the

SLO, opposition and resistance to new projects continue unabated in developing countries, and new anti-mining social movements continue to emerge.

Moreover, mining companies often use job creation and employment opportunities to cull local resistance. For instance, Roe and Samuel (2007) report that districts hosting mining activities record lower levels of poverty than neighbouring districts without mining concessions in Ghana and Tanzania. Meanwhile, communities within mining districts experience disparities in income levels; those closer to mines observe higher incomes than those farther away (Standing and Hilson 2013). Employment opportunities from the mining industry can be promising, though. But, the extents to which this addresses local labour redundancy cannot be explained, especially, in recent times where labour requirement is reduced by technological automation of most industry activities. Besides, rural households take a longer term view of livelihood security than merely taking advantage of short-lived and unsustainable choices presented by companies. Thus, in recent times job creation cannot be an efficient mechanism for managing conflicts in mining regions.

1.2.2.3 Scientific Approaches

The scientific research community often suggest the use of economic land use theories for resolving land use conflicts in mining regions. That is, the use of the present discounted land use value, counting on the difference of land rent between competing objectives at a given time (Struck 1975; Walker 2004; Schueler, Kuemmerle and Schröder 2011; Akabzaa 2000). Thus, the land development objective with the highest land rent should be awarded land use rights and the existing occupant should be displaced. However, in developing countries accurate measures of living standards and economic returns of land use activities are often inadequate to compare with mineral resource market values. Besides, most local communities in rural landscapes are subsistent and do not produce for markets, though some farm products are sometimes traded to provide certain pressing needs of families. Therefore, a comparison of the economic rent between mining and subsistence agriculture, for instance, cannot provide an accurate measuring standard to inform land allocation. Nonetheless, it is recognised that rural development problems are manyfold and cannot be addressed by agricultural programs alone. Rather, an integration of agricultural and non-agricultural strategies would promote economic and social development in the countryside (Yaro 2011).

Cost-benefit analysis is, therefore, proposed in lieu of the land rent approach (Akabzaa and Darimani 2001). These proposals imply that communities are willing to compromise, where the mining sector activities are found to have minimal negative impacts on their land use interests. Conversely, the United Nations guiding principles on business and human rights (Mares 2011) warns that compromise systems are obnoxious for sustainable economic futures of communities. Also, economic returns are elementary functions of social values in developing countries. In this case, land use allocations would defy the provisions made in the ILO Convention 169 to which most developing countries have ratified. Besides, since the publication of the Brundtland Report (WCED, 1997), Convention 169 (International Labour Organisation 2013) and the Agenda 21 of the United Nations Commission on Environment and Development (UNECD) (1992), the attention of scientists and policy makers has been drawn towards putting rural communities at the centre of land use planning and resource creation. Thus, the potential impacts of mining sector projects must be quantifiable and linked with long-term sustainable development objectives of host communities.

To this end, Geographic Information Systems (GIS)-based suitability analyses have been widely applied in various domains of rural resource management (Malczewski 2004, 2006; Kiker et al. 2005). Suitability analysis is an effective tool for land use conflict prevention and cost benefit analysis (Eastman, Jiang and Toledano 1998). The procedure takes into account sustainable development, economic development, and social values often attached to resource development in local areas (Malczewski 2006). For instance, Carr and Zwick (2007) used suitability analysis approaches to develop models for identifying both existing and potential land use conflicts among multi-objective land use interest groups. Mwasi (2001) also used GIS-based suitability analysis for resolving land use conflicts between pastoral farmers and sedentary workers in Kenya. Further, Sedogo (2002) used GIS techniques to map conflicts in respect of land degradation and conflict identification in Burkina Faso. GIS-based techniques have been applied with remote sensing for land use change analysis and impacts of mining on adjacent land usages. Examples include Sonter et al. (2014), Townsend et al. (2009); Schueler, Kuemmerle, and Schröder (2011).

However, multi-objective land use suitability models often involve weighting of land use objectives. The models might be difficult to apply in conflict management situations in developing countries, where communities have prejudice against the mining industry. Moreover, legislative policies entrench compulsory land acquisition, resource extraction and community displacement against the development objectives of local communities. Hence, the use of weighting according to importance in GIS-based suitability analysis cannot reconcile these opposing parties, each taking a fixed position. Besides, it cannot be assumed that rural land use issues can be solved with standardised measures, regardless of location or culture. Rather, standardisations further deepen the structural inequities between the communities on one hand, and governments and companies, on the other. The existence of inequities between stakeholders is identified as a major factor of resistance (Beatrice 2013).

In spite of improved efforts of the mining industry, and policy interventions of governments, corporate financiers and the scientific community, company-community conflicts are on the rise in developing countries (Hodge 2014; Bebbington et al. 2008). The mining industry, governments and the research community continue to stick to qualitative and structural mechanisms for managing company-community conflicts. While the number of exploration and mining concessions granted are increasing in these countries (Shaw 2015), on the ground local realities that stimulate the similarly rising conflicts between the mining industry and local communities are still unclear. Besides, most scientific studies focus on the aftermath negative impacts of the mining industry on local communities rather than develop models that can be used to mitigate these impacts and improve the relationships. Examples include Akabzaa (2000); Kitula (2006); Erdiaw-Kwasie, Dinye, and Abunyewah (2014); Moran and Brereton (2013). Scientific studies that attempt land use conflict management do not lend themselves applicable at the village level in mineral-rich developing countries, where people do not understand the environmental and livelihood implications of choices made over land use. Meanwhile, without informed local participation in negotiations, the existing structural inequities and power difference between governments, industry and local communities cannot be bridged for sustainable solutions in these areas.

This study, therefore, maps and analyses on the ground realities that stimulate land use conflicts, specifically relevant to minerals exploration and mining in the emerging northwest gold province of Ghana. The study further develops replicating models to optimise rural resource development, and for managing potential land use conflicts in the area. The findings would enhance Ghana's contribution to a realisation of the industrialisation and economic growth goals of the African Union, and the

African Mining Vision in particular (African Union 2014; African Mining Africa Mining Vision 2011).

1.3 Theoretical framework

This research probes the livelihood parameters and resource development objectives of local communities, quantifying land resources on which production depends, whilst at the same time recognising the land use interests of governments and mining companies. This is a multi-objective land use situation, comprising parallel interests among diverse stakeholder groups. Multi-objective land use consists of complementary objectives and conflicting objectives (Eastman, Jiang and Toledano 1998).

Complementary objectives are land uses that are not mutually exclusive, but can coexist; one has more importance than the other, though. An example is recreational and wildlife land uses. On the contrary, conflicting land use objectives are mutually exclusive. That is land use objectives compete for available space that can support a single objective at a time (Malczewski 2006). An example is mining and agriculture and other local land uses. Hence, this study includes interpretative and prescriptive conflict analysis techniques (Eastman, Jiang and Toledano 1998). Interpretative analysis examines conflicts about natural resources by identifying the parties involved, their land utilization objectives, and the extents of conflict areas (Eastman, Jiang and Toledano 1998). Prescriptive Analysis is a remedial approach that seeks to institute conflict prevention and management measures, such as mediation, in mining regions (Andrew 2003).

Mining related conflicts are a complicated predisposition that can be understood better in the context of N-persons Non-Zero Sum Game theory (Rapoport 2012; Hodge 2014). This theory is a conflict management approach that revolves on strategic thinking, analysis, and understanding of conflicts and means of possible cooperation (Rapoport 2012). Zero-sum game is a decision making situation where the simultaneous actions of all actors involved in a competition lead to losses to all parties (Turocy and von Stengel 2001). An example is a protracted conflict between exploration or mining companies, state governments and local communities.

On the other hand, the two-persons-zero-sum game involves only two actors where the gain of one results in loss to the other. Examples include the case of conflicts between state-backed exploration and mining companies, and forestry, or agriculture or local communities. The theory is efficient in bridging power balance gaps between conflicting parties, subject to accessibility of information and knowledge to all (Cubitt and Sugden 2003). In the context of resource development, the decisions of one stakeholder affects the interests of the other. Thus, the main goal of the game theory is to predict the strategies, possible actions and outcomes of each rational player involved. It also accounts for the level of information available to each that might pre-empt its actions and consequences.

However, local communities do not often have full access to spatial information neither do governments nor companies have full understanding of local realities and reactions. This presents a shared risk situation where companies are uncertain of the mining project feasibility; whether there will be viable recoveries or not. Local communities are also uncertain about their livelihood resources; the spatial extents of new approvals and the magnitude of potential impacts of displacement on livelihood. Thus, the game theory proves useful in analysing multi-objective and multi-criteria decision making (MCDM) glitches in the resources sector (Madani 2010). It helps to measure displacement indicators as thresholds and standards based upon which mining-induced conflicts can be identified, defined and assessed. For instance, non-cooperative game theory approaches can predict the outcomes of decisions and reactions of each stakeholder in mineral resource development. With this knowledge, possible peaceful coexistence can be efficiently mediated between mining companies and communities.

Moreover, non-cooperative game theory considers an analysis of all possible outcomes in the interactions, including potential cooperative outcomes. Under the non-cooperative game theory, all stakeholders (local communities, companies, and governments) are assumed to be egocentric and rational (Osborne 2004). Each stakeholder is critical and curious about potential and existing impacts imposed on them by the decisions and actions of the other. The game theory allows observations and considerations of non-cooperative behaviours (Rapoport 2012), which is the worst form of resistance to resource creation and often underestimated by other methods. Non-cooperative behaviours do not align with criterion weighting and tradeoffs.

A major reason for preference of the game theory over conventional methods is that, it allows a systems engineering approach to achieve optimal outcomes

(Osborne 2004; Hodge 2014). That is, flexible uses of both interpretative and prescriptive conflict analysis approaches to address environmental, socioeconomic and various operational characteristics of mineral resource development problems, with cognisance to the self-centric attitudes of stakeholders. It does not require detailed quantitative information and expressions such as standardised land use preferences, rent and absolute income levels of household, farm yields, and living standards of rural communities (Madani and Lund 2011).

1.4 Study objectives and research questions

1.4.1 General objective

The main objective of this study is to provide a multi-objective space analyses for managing potential land use conflicts between local communities, mining industry, and other land use interest groups in the landscape. Specifically, the study seeks to:

1. Develop methods for identifying the potential impacts of exploration and mining activities on local communities' livelihood; and explore the dynamics for addressing issues emanating from these defects;
    - Q1.1. What are the major livelihood activities in the locality?
    - Q1.2. How do large-scale exploration and mining activities affect local communities' livelihood; degenerating conflicts?
    - Q1.3. What could be the magnitude of the impacts of exploration and mining activities on local livelihood foundations?
2. Assess exploration and incipient mining operations conditions that would contribute to the development of both typical and atypical environmental stress; generating social disruptions and disputes
    - Q2.1. Can existing spatial conditions support the mining sector activities, while at the same time provide resources for primary production?
    - Q2.2 What are the potential extents of land degradation instigated by mining and exploration? Are the potential impacts on populations quantifiable?
    - Q2.3 Does the mining sector determine the allocation of rainwater, groundwater and surface reservoirs for primary production and domestic uses?

3. Identify areas of high environmental sensitivity and cultural value for supporting sustainable resettlement of potential displaced communities
    - Q3.1 Is mining-induced resettlement and impoverishment of displaced local communities an avoidable option?
    - Q3.2 How can sustainable resettlement options be modelled in the local landscape?
    - Q3.3 Can there be meaningful negotiations between communities, governments and companies?

1.5 Structure of the thesis

This study investigates the premise that resistance against large-scale mining sector in areas that do not have relevant previous experiences with the mining industry activities is a function of perceived displacement of local livelihood activities (Thomson and Joyce 1997). Therefore, **Chapter One** introduces causes of mining related conflicts, areas of conflicts and the inter-sectoral, international, national and scientific mechanisms of managing these conflicts and the challenges laden with these mechanisms. To this end, selected objectives are suggested to answer salient research questions on multi-objective spatial modelling of mining regions in developing countries. To achieve these objectives and research questions, **Chapter Two** describes the research design and fieldwork protocols based upon which: (i) primary data were developed at the local community level and (ii) some secondary data were also obtained. The chapter, further, explains methods used in analysing the data, although, the various chapters have given detailed explanations of the steps of each model used.

Thus, the study is divided into three major parts. Each part contains chapters that are based on published materials in refereed journals and conference proceedings. **Part 1** consists of **Chapters Three, Four**, and **Five,** which identify and discuss mining sector development and socioeconomic issues at both district and village levels. The study groups socioeconomic activities into agricultural and non-agricultural and each is explored together with the mining sector interests. Especially in Africa, rural communities are linked by ties of economic and social relations (Ellis 2000). Developmental and policy decisions affecting these communities are managed at the district-wide level (District Profile 2013). Besides, the mining sector policies in Ghana grant that first point consultations should initiate at the district level, scaling down to the affected communities so that, adjacent communities would also have the opportunity to make meaningful input before final decisions are made on resource exploration and extraction (*Minerals and Mining Act* 2006).

Hence, mining leases in the study districts were measured and used for spatial analysis of the interactions between mining sector activities and agriculture; to have a district-wide perspective of issues. Thus, **Chapter Three** identifies issues of latent conflicts between the mining sector and agriculture at the district level. The chapter investigates: (i) the strength of agriculture as a livelihood activity of rural-folks in the area; (ii) the spatial extents of mining sector projects and; (iii) their potential interferences with agricultural suitability in the local landscape. Finally, in this chapter, the expected role of District Assemblies, towards curbing mining industry and community conflicts, is also discussed.

Chapter Four is an in-depth study of chapter three; focusing on the village level perspectives of potential impacts of the mining industry activities on livelihood base due to land displacement. Unlike chapter three, this chapter combines and studies both agricultural and non-agricultural activities at the village level, where division of labour and specialisation is not always explicit (Scoones 1998). An example is the local manufacturing industry, which is closely associated with on-farm agriculture and trading and, therefore, points to the strong links between rural economic livelihood and space. In the savannah regions of sub-Saharan Africa, the Shea processing industry is the most dominant example of such rural non-agricultural livelihood activities that contribute to community lifestyle (Schreckenberg et al. 2006).

Thus, Chapter four addresses two major issues: (i) provides spatial reference and information of the land area of communities intersected by mining interests, which is normally lacking in developing countries (Cuba et al. 2014) and; (ii) evaluates the spatial associations between the major diversified rural livelihood activities so as to provide evidence of the possible impacts of the mining sector activities on the total livelihood of rural communities. It could also form the basis of community concerns for attention during negotiations with mining companies and governments. A special focus is on the Shea industry as a major source of non-agricultural rural livelihood in the area. Thus, the chapter particularly gives a gender dimension to the analysis, which most scientific studies do not specifically address. Hence, the study asserts that a mining-induced displacement of agricultural lands would have a cumulative effect on the non-agricultural livelihood systems of affected communities. This cumulative effect could be a precursor of a district-wide resistance since rural communities host the 'food basket' and resource base of urban areas globally (Scoones 1998).

Based on an in-depth knowledge of the economic significance of future Shea displacement at the villages, on whose lands mining rights have been granted, **Chapter Five,** therefore, discusses the major non-agricultural livelihood activities at the district level, with a special focus on the spatial interactions between the Shea industry and mining land use interests. The chapter demonstrates the connections between the rural economy and the pervasiveness of impacts of land displacement across a wide-range of populations at the district level.

Part 2 comprises of **Chapters Six** and **Seven** that describe the environmental implications of mineral resource development on both agricultural and non-agricultural livelihoods, and potential conflicts. The chapters in this part, therefore, have been analysed in respect of a rising environmental conscience against large-scale mining sector activities in developing countries (Keeling and Sandlos 2009; Earthworks 2004). This part, specially, looks at the potential impacts of exploration and mining on land degradation, and water stress in a regional perspective.

Chapter Six presents a critical analysis of the potential socioeconomic effects of land degradation and displacement due to the mining sector activities. For instance, Schueler, Kuemmerle, and Schröder (2011) showed that surface mining led to: (i) displacement of farmlands and, (ii) the removal of forest trees that have economic value to rural communities in western Ghana. This effect also resulted in the clearing of native vegetative cover to make way for on-farm agricultural activities, further exposing the land to erosional hazards such as soil loss and diminishing agricultural productivity. Importantly, land degradation plays a significant role in the cycle systems of both ground and surface water sources (Sophocleous 2002). For instance, surface mining exposes land to soil erosion by water, which can lead to streambed sedimentation and water pollution (Keesstra et al. 2012; Mbaya 2013). Therefore, **Chapter Seven** analyses the potential cumulative effects of mining-induced land degradation and mine operations on surface and ground water availability in the study area. In this chapter, focus is on the major ways through which mining sector activities contribute to water stress, especially, in regions that have low capacity to purify water for domestic, industry and commercial uses, and linking these to potential conflicts in the study area.

Part 3 uses non-weighted spatial suitability analysis to design sustainable resettlement of potentially displaced communities or relocation of land use activities and land reclamation from mining. It considers this perspective at the community, district and region-wide levels. Thus, **Chapter Eight** presents an approach to mapping spatial suitability in mining regions. This approach defies customary GIS approaches in suitability analysis in that, it does not require the use of standardisation, objective preferences and degree of importance for land allocation and conflict management. Rather, the chapter presents environmental limitations, opportunities and potentials for supporting mineral resource development, agricultural and non-agricultural livelihood activities in the local landscape. It identifies areas that may be suitable for resettlement or relocation of livelihood activities in a regional outlook in the event of mining sector-led displacement.

Finally, **Chapter Nine** discusses procedures, major findings and conclusions of the study. The chapter further discusses potential contributions of the findings to policy planning, support decision making and academic development, particularly in land use conflicts management. It also identifies links between the findings of the study and objectives of the African Mining Vision (AMV); and the post-2015 development agenda of the African Union. Finally, this chapter provides some recommendations on the need for future research in the study area.

1.6 The study area

Given the economic importance of mining to Ghana and trying to determine its potential impacts, opportunities and limitations in an emerging region, a brief knowledge of the regional socioeconomic and biophysical background is essential to understanding the analytical methods. The study area is located in the Upper West Region (UWR), up the north-west of Ghana. It is the youngest region in Ghana, carved out of the then Upper Regions in 1982, with Wa as the regional capital (Fig. 1). The region has a total population of 702, 110 (Table 1) with high densities occurring in the western side of the region. This has adverse implications on land use including land degradation, loss of fertile lands due to associated reductions in fallow periods of farmlands and over grazing. The region covers a land area of approximately 18,476 square kilometres, about 12.7% of the total land area of Ghana. Further details of the biophysical and socioeconomic characteristics of the study area are presented in succeeding chapters.

CHAPTER 2 Research Design

2.1 Introduction

Conflicts over resources could be manifest or latent (Buckles and Rusnak 1999). Due to social norms and ethics, some groups would usually avoid public confrontations, as far as resource management is concerned. Several reasons may also make conflicts appear non-existent, though. These include fears at the initial stages of exploration, distrust, peer pressure, and exclusion (FAO 2000; Thomson and Joyce 1997). But depending on the level of social cohesion in communities, these afore mentioned could also be strategies for an aggregated response; which is a major characteristic of latent conflicts (Buckles and Rusnak 1999). The escalation of latent conflicts has several dimensions, which lead to violent confrontations, disrupt projects and undermine livelihoods (FAO 2000). This may be possible if there is inadequate participation of local stakeholders, unaddressed anticipations, fears and potential threatening situations, and lack of effective mechanisms (FAO 2000; Jenkins 2004).

In this connection, this study conducted fieldwork to establish an all-inclusive set of land use conflict indicators, specifically relevant to minerals exploration and mining in the emerging northwest gold province of Ghana. To meet this aim, the following specific objectives have been pursued: (a) identify existing land use activities, land cover and land occupancy of the study area, in-situ; (b) understand the performance of current production patterns and results matrix of the study area (c) appraise the environmental resource base of the area; local definition of resource creation, as well as land use objectives (d) appraise the bio-physical and socio-economic conditions of the area; (i) Bio-physical conditions include rainfall, topography, geological extents, soils, and water resources (ii) Socio-economic conditions include agricultural sector, non-agricultural sector and human population.

It is clear from earlier research that a single approach to mining-related land use conflicts management is not feasible, rather an integrated approach is required (Jenkins 2004; Bebbington et al. 2008). This study, therefore, adopted the systems engineering approach, which provides room for creative flexible solutions, and collaboration among stakeholders. This originates from two schools of thought: Strategic Environmental and Socioeconomic Assessments, and Collaborative Planning (Hodge 2014; Craynon et al. 2015; Prno and Slocombe 2012; Akabzaa and Darimani 2001). The systems engineering approach suggests a simultaneous analysis of factors that generate community concerns: socioeconomic and environmental. To use this approach, a combination of participatory rural appraisal (PRA), spatial analysis tools and regional economic analysis models has been useful. This combination allows the spatial analysis of specialization of districts and communities in a particular activity; the level of association between socioeconomic and environmental variables; their interactions with mineral resource developments objectives; and identification of potential areas of conflicts between these factors.

2.2 Study area

Taking a case study area in Ghana is relevant based on the fact that, Ghana is among the top ten world's largest gold producing countries and second in Africa (Mines 2013). Apart from gold, Ghana also remains the third largest producer of aluminium and manganese ore in Africa, and a significant producer of bauxite and diamond (Amponsah-Tawiah and Dartey-Baah 2011; Bermúdez-Lugo 2012). Deposits of Uranium and Copper are recent discoveries and further exploratory works are still going on in many parts of the country, especially along the Northern regions.

The country has also been largely dependent on its agriculture sector for export earnings, local food supplies, and rural livelihood sustenance (Brooks, Croppenstedt and Aggrey-Fynn 2007). Indeed, Ghana's economy is dominated by the agriculture sector in terms of its share of Gross Domestic Product (GDP), employment, foreign exchange earnings and provision of food security (ISSER 2013). The agriculture sector currently employs about 76.1% of the rural labour force (GSS 2012a). The total population engaged in agriculture in Ghana is given as 13,366,340 representing 54.2% of total national population and 45.8% of household population (GSS 2013). Average household size in agriculture is given as 5.3% while general household size is 4.4%. Out of this figure, rural areas account for 73.5% of agricultural households (GSS 2012b). Nationwide, over 70% of heads of agricultural households are males and about three quarters are rural dwellers. This reinforces the hypothesis that agriculture is a rural phenomenon (Yaro 2006b).

The interplay of these two major economic drivers (agriculture and mining) of Ghana reveals a trend of land use conflicts and they continue to increase since mineral resource exploration is marked to increase in the countryside (Dlouhá and Barton 2014). On this basis, it is justifiable to conduct a case study in Ghana to develop models that can be replicated for managing land use conflicts in other mining regions in the global south.

2.2.1 Upper West Region (UWR)

Upper West region has been rated by the Ghana Living Standards Survey (GLSS-5) as the second poorest region in the country after the Upper East Region (GSS 2007). The region shares boarders with Burkina Faso in the West and up North; Upper East Region in the East; and Northern Region in the South-East and South. Before the 2010 Population and Housing Census (PHC), UWR was divided into nine local governing areas known as districts in Ghana. These were: Wa municipal, Nadowli, Wa West, Wa East, Sissala East, Sissala West, Jirapa, Lambussie-Karni, and Lawra districts (table 1 below). After the 2010 Population and Housing Census (PHC), in accordance with Section 243(1) of the 1992 constitution and Section 20(1) of the Local Government Act 1993, Act 462, two more new districts have been created giving a total of eleven districts in the region. Thus, the new districts are: Nandom separated from Lawra district and; Bussie-Daffiama-Issa district separated from Nadowli district. However, formal administrative boundaries and associated details of the newly created districts were not yet ready as at the time of fieldwork.

Table 1: Districts, Population and Type of locality: Upper West Region (UWR)

District	Capital	Total Population	Urban	Rural
All Districts	Wa	702,110	114,653	587,457
Wa West	Wechau	81,348	Nil	81,348
Wa Municipal	Wa	107,214	71,051	36,163
Wa East	Funsie	72,074	Nil	72,074
Sissala East	Tumu	56,528	10,627	45,901
Nadowli	Nadowli	94,388	Nil	94,388
Jirapa	Jirapa	88,402	12,716	75,686
Sissala West	Gboluu	49,573	Nil	49,573
Lambussie Karni	Lambussie	51,654	6,869	44,785
Lawra	Lawra	100,929	13,390	87,539
Nandom (new)	Nandom	46,040	6,898	39,142
Daffiam-Bussie-Issah	Daffiama	32,827	Nil	32,827

Source: Ghana Statistical Service, 2010 Population and Housing Census (PHC)

The population density in the region is 38.0 persons per square kilometre (GSS 2012a). However, within the region there are variations across districts and even within the same districts variations exist across villages. For example, the Nadowli district records 35 persons per square kilometre; observing 54.3 persons per square kilometre around Nadowli and Kaleo in the west, and 17 persons per square kilometre at the eastern side of the district (Assembly 2010). The 2010 Population and Housing Census show that the UWR has the lowest population (2.8%), and the highest rural population concentration (83.7%).

2.2.2 The Wa-Lawra Greenstone Belt

In this study, communities have been sampled across six out of the seven studied administrative districts. The districts are: Wa West, Nadowli, Jirapa, Lawra, Nandom, and Lambussie-Karni Districts. These together make the Wa-Lawra belt in Ghana. The Wa-Lawra belt has been under mineral exploration since the late 1940s (Adu 2003). Consequently, the belt has been tagged in recent times as “the Emerging Ghana’s North-west Gold Province” due to recent discoveries of world class gold deposits in commercial quantities (Coffey 2012). The extents of the study area are typically rural with Jirapa, Lawra, Lambussie and Nandom being the only urban centres. The climate of the study area is summarised by conditions in the synoptic stations at Babili, Cherekpong, Lawra, and Nandom respectively. The area experiences a uni-modal rainfall regime lasting 5-6 months and a long period of drought lasting 6-7 months in the year, usually from October to the end of April. Average annual rainfall, temperature, relative humidity, wind speed, sunshine hours and solar radiation from 1996 to 2013 are 885 mm, 28.6 ^{0}C, 54 %, 81 km/day, 7.9 hours and 20.4 MJ/m^{2}/day respectively (GMET 2013).

2.3 Fieldwork data collection protocols

Two fieldwork and data collection were carried out from November to February, 2013/2014; and 2014/2015 respectively. This period was chosen for the fieldwork because, communities are less busy from on-farm activities; farmlands are cleared, grasslands, streams and rivers all dry-up and the landscape is accessible. Communities have not been sampled from the Wa East district due to resource and time constraints. Nonetheless, 20 geographic coordinates of landscape features were randomly sampled from this area for satellite imagery calibration. The features include water bodies, dwellings, closed savannah vegetation, extruding rocks, and farmlands. The fieldwork was arranged through three key stages, namely: (1) Community Entry and Ground Preparation, (2) Data Collection and Resource Inventory, and (3) Data Validation and analysis.

2.3.1 Community entry and ground preparation

Courtesy calls were payed and applications letters for consent were submitted to the Regional House of Chiefs and all District Assemblies covering the study area to seek their permission and consent of participation. Verbal approvals were granted after several follow-up meetings with the local authorities; District Assemblies and the unit committees of the sampled communities. Another important consent needed was from the Savannah Accelerated Development Authority (SADA), to take custody of data generated from the fieldwork for future application. This saves the aim of the research from being restricted to a mere academic discourse. SADA is a constitutional authority with the mandate to facilitate bridging the economic and developmental gap between the northern savannah belt and the rest of the country.

Three separate visits and discussion forums were held at the sampled communities. The first workshop aimed to; (a) introduce the objectives of the research to community leadership, and (b) learn the values and development objectives of the localities. The assemblyman of each community was usually the first point of contact before the unit committee and then village chiefs, respectively. These leaderships also met to discuss the significance of the research among themselves. Community leadership engaged some very important community members who do not occupy leadership positions but are deemed to have good ideas about community's development objectives. After reflections, feedback and permissions were granted to conduct the fieldwork in the communities. These feedbacks were communicated through phone calls.

The main objectives of the second visits were to: (i) appreciate the expectations and areas of likely support from the villages (ii) identify participants in the field data collection and, (iii) conduct site reconnaissance to familiarise with the area; establish control points for data geo-referencing, identifying potential challenges, mitigating factors and opportunities. A potential challenge identified during the reconnaissance was a lack of electricity at some of the villages, including Orifane, Nanga, and Yiziiri. Therefore, during the visits a portable electricity generator was rented to these villages to facilitate the use of field resources such as laptop computers and projectors.

On the third visits, meetings were held in each community and village with the local participants. The purpose of this round was to: (i) give a detailed explanation of the objectives, significance, and expectations of the fieldwork to the participants, (ii) define the roles of all participants in the fieldwork process, (iii) formulate operational protocols like ethics of a meeting, develop timetables for work, routes for transect walk, and recognise the different needs of individual participants during the data collection and, (iv) design databases and carry-out activities. Overall, the entry and ground preparation phase lasted for approximately five weeks, including weekends.

2.3.2 Data collection and community resource inventory

Focus group discussions and participatory mapping were the two principal techniques employed during the fieldwork and primary data collection. These techniques have been lauded for their usefulness in generating non-existent data at the local community level (Chambers 1994; FAO 2002). This section is divided into secondary and primary data collection components

2.3.3 Secondary data collection

The first two weeks of the fieldwork were basically used to set the pace for [1]secondary data collection. Application letters were written to both public and private institutions, who are deemed to have custody of relevant data. Principal sources where data were obtained include; the Department of Geography and Resource Development, Earth Science Department, University of Ghana; Soil Research Institute of the Council for Scientific and Industrial Research (CSIR); Ghana Meteorological Agency (GMA); Ghana Statistical Service (GSS); Environmental Protection Agency (EPA); Ghana Water and Sewerage Company (GWSCL), and [2]Azumah Resources Pty Ltd. A lot of earlier research works have been done in the entire Wa-Lawra belt in which the major geological features and soil series have been established. Previous researches have also documented the road networks, drainage system, population and housing census, economic conditions, and topographical features of the area for purposes other than the objectives of this research. Hence, this field research stopped short of conducting fresh data collection on the above geographical features of the study area. Rather, a review of the pre-existing data was done to validate, update and rectify lapses.

[1] Secondary data is information contained in an earlier research report or database.
[2] The only exploration/mining company currently holding concession licenses in the area

Wherever lapses were noticed during the primary data collection, appropriate measures were taken to re-inforce data accuracy and robustness.

2.3.4 Primary data collection

2.3.4.1 Sampling

Considering the variables of the study, a multi-stage sampling technique was employed for the primary data collection. The study area was defined in clusters of settlement communities on district basis. The frame was to draw in communities: (i) whose names are used by the exploration companies to label lease areas, (ii) transcended by an active mine concession and exploration targets, (iii) with larger number of settlements. The sampled communities are Eremon in the Lawra district; Kokoligu in Nandom district; Nanga, Tangasia and Yiziri in Nadowli district; and, Yagha in Jirapa district. Eremon covers a spread of twelve villages and settlements, namely: Yagra, Yagra-Tangazu, Zinpeni, Dazuur Baapari, Naburnye, Toto, Nayiribog, Danko, Sorguong, Bure, Dazuur Songor and Bompari. Yagha community comprises of the following settlements: Yagha-Gbaani, Yagha-Tohaa, Yagha-Baapari, and Yagha-Kusoglo. Tangasia, Yiziiri and Nanga share the mines concession land area called Kunche in the Nadowli-Kaleo district. Kokoligu comprises of Kokoligu central and Kokoligu Gbantakuri. Representatives of the exploration and mining companies informally confirmed the status of their activities in these communities.

The following community and village groups were recognized for the focus group discussions: women associations, youth associations, and area council and unit committees. Each of these groups appointed a trusted person, who is deemed to have enough knowledge of the community resources and development objectives, to represent it in the fieldwork activities. The District Assemblies were also represented by the assemblymen of the communities and members serving the “Mining and Land Issues Sub-committees” of the district assemblies. Informal discussions were held with some district administrators as well.

2.3.4.2 Focus group discussions

Focus group discussions were done during the third visit to each village and community. Over all, a minimum of 10 participants were involved in the focus group meetings. Nonetheless, other important opinion leaders, who do not fall in any of the identifiable groups, were also involved in the focus group discussions. This category of individual community experts includes experienced farmers, hunters, and earth priests. In some villages, more interested individuals joined the discussions and made invaluable contributions to the subject. Each focus group discussion lasted for a maximum of 4 hours. The exploration company with current tenements and concession in the area declined to participate in the group discussions. All efforts, including emails and personal visits, to get them on board were to no avail. Non-Governmental Organisations (NGOs) were not also represented. Upon consultation with the district assemblies, it was observed that NGOs with land development objectives in the area had completed their projects and vacated site at the time of fieldwork. The following major questions were pursued during the focus group discussions:

1. Which livelihood opportunities exist in the area in respect of?
    a. Animals harvested or reared for food, clothing, medicines, sacrifice, leather or diary;
    b. Plant materials harvested for food, clothing, medicines, shelter, tools, income;
    c. Rocks, and soils collected for making tools, conducting ceremonies, shelter, rent, farms;
2. What are the bases of land allocation for a development objective?
3. Which parts of the land of the area can be leased or sold (by whom)?
4. What mechanisms are in place for checking land encroachment or poaching?
5. Identify the bio-physical factors that affect land use decisions in the community
6. Identify areas likely to relocate to in case of displacement by any external phenomena (e.g. natural hazards)
7. Give reasons for the choice of site of potential relocation

The choice of only focus group interviews was dictated by the communities. Reasons given included that stakeholders of the mining industry interest usually interview individual community members and draw conclusions that do not represent their collective interests. Hence, individuals are banned from granting interviews related to exploration and mining in the communities; individuals were also unwilling either. However, semiformal, unstructured interviews were granted by local authorities at the District Assemblies and the Savannah Accelerated Development Authority

(SADA). Overall, 25 local authorities, including SADA, were interviewed, and a minimum of 530 community members participated in the focus group discussions.

2.3.5 Participatory mapping and resource inventory

An intensive investigation was conducted using participatory mapping and resource inventory at all sampled villages. Participatory mapping involves all stakeholder groups in sketching land cover; land use; and land occupancy maps of their community on cardboard paper. The above lead questions facilitated this process of the fieldwork. Emphasis was on community resource and most valuable areas. The mapping sessions were joined with the focus group discussions for purposes of effective time management. The following itinerary was employed during the participatory mapping activities:

Sketch the land use/cover patterns of the community showing;

1. Places where animals are harvested for food, clothing, medicines, sacrifice; or where these activities are prohibited;
2. Places where plant materials are harvested for food, clothing, medicines, shelter, tools, rent; or where the above activities are prohibited;
3. Places where rocks, minerals, and soils are collected for making tools, conducting ceremonies, shelter, rent, farms; or where these activities are prohibited
4. Places of religious value (sacred sites)
5. Human habitation

2.3.6 Timelines, transect walks and data validation

The participatory mapping was done simultaneously with timelines to identify land use/cover changes experienced in the communities over three decades (1984-2013/2014). 1984 has been chosen as the start year because, it marks a period of famine in the history of Ghana and the northern savannah areas were worse-hit. The following guide questions were used:

1. Review the community’s land use history
2. Describe the community’s land condition from 1984 to present
3. Explain the reasons of land use change in the community

4. Define the socio-economic factors that affect land use decisions in the community
5. Draw sketch map showing the land use and land constraints of the community

As part of the participatory mapping activities, transect walk was conducted around the communities to take the geographic coordinates (geo-reference) of the sketched maps features. This activity ensures accurate spatial data representation and secondary data calibration. A handheld global positional system (GPS), with 5 metres positional accuracy, was used to pick the coordinates. These coordinates were respectfully recorded in a field notebook.

During transect walks, land use/cover types were photographed for enhancing satellite imagery interpretation and analysis in the area. Community representatives also cross checked and rectified any detail omissions or commissions on the sketched community maps. Examples of features captured on the sketched maps that have been used to validate satellite imagery include the Black Volta, and the Crocodile Ponds and dam in Eremon and Gabilee. The sketched maps have been digitised in GIS environment using their respective geographic coordinates and used for spatial analysis of the respective communities.

2.4 Findings

2.4.1 Socio-economic characteristics

The following secondary data were obtained through the fieldwork: data on economic activities, and population and housing census for all districts within the study area were obtained from the Ghana Statistical Service (GSS). District profiles were also obtained to extract districts specific data. District profiles contained some socio-economic information about the entire local government area. Examples include data on agriculture; cropping area, performance, and livestock keeping. However, detailed data on agricultural activities at the district level have been obtained from the GSS. These include household populations engaged in agriculture; crop cultivation, livestock keeping, tree planting and fishing. Primary data generated from sampled communities include: Economic/livelihood activities, housing and population data.

2.4.2 Bio-physical characteristics

The following secondary data have been obtained through fieldwork: Polygon shapefiles of geology, soils, upper west region, forests, hydrology, topography, road network and land cover were obtained from the Department of Geography and Resource Development, and Department of Earth Science, both in the University of Ghana. Polygon and point shapefiles for all districts and communities were also obtained from the Ghana Statistical Service (GSS). Rainfall data were also obtained from the Ghana Meteorological Agency (GMA). Hardcopy soil suitability maps were obtained from the Council for Scientific Research (CSIR) of Ghana. These have been digitized and used in the analysis. Tenements; exploration and mining concession maps were downloaded and digitized from the report 43-101 of the company operational in the area as at the time of fieldwork. Geographic coordinates of about 74 borehole locations were also obtained from the Ghana Water and Sewerage Company (GWSCL). Primary data obtained from sampled communities during fieldwork include sketched Land use/cover maps. Others are geographic coordinates of about 94 existing boreholes, 10 dams, 1 major river (Black Volta), 3 major tributaries (Kulkpong, Kamgba, Bakpong), 30 streams and 4 large hillocks.

The concessions map was obtained from report 43-101 that was downloaded from Azumah Resources website. These data were digitized into polygon shapefiles in ArcMap. Azumah Resources is an Australian resource company currently holding exploration and mining leases in the upper west region. It would be noted that Azumah resources owns all 13 exploration leases in the region, of which two have been awarded mining rights (Azumah Resources Limited 2013). The company currently enjoys monopoly over exploration and mining activities in the area (Washbourne 2014). This is confirmed by the Ghana minerals commission and the environmental protection agency. Although it is estimated that one out of every ten exploration activities progress to mining (Singer and Kouda 1999), exploration activities discourage communities from investing further on lands under concessions (Twerefou 2009; Cernea 2003a). Lands currently under exploration lease would be valuated according to their value at the time exploration licenses were granted, should viable quantities be recovered for future extraction (Avcı, Adaman and Özkaynak 2010; Akabzaa 2000; Twerefou 2009). Besides, exploration activities cover a whole lease area and companies dig for samples within the spatial extents. Also, mining concessions expand over time; related activities such as road construction, housing, water and powerline constructions all involve space that is not originally granted under concessions. It is, therefore, worthwhile considering the entirety of concessions in spatial analyses.

2.5 Data analysis

Geographic information science (GIS), including geographic information systems (GIS) and remote sensing, aided in the analysis of spatial interactions between communities' and mining land use interests (e.g. exploration and mining leases, water resources, agricultural and non-agricultural lands). Through GIS analysis of the on-the-ground issues related to displacement and livelihood, key parameters to be considered in resettlement decision-making were identified. This type of analysis is crucial to ensure that local communities do not lose at the gain of future mining operations. Other spatial analysis tools employed are the location quotient (LQ) and location association (La) models, and the input-output model was also used for the regional economic analysis.

2.5.1 Location quotient (LQ) model

The location quotient (LQ) model has been used to measure the degree of specialisation of each district and community in an industry. The LQ model is also used to measure and predict changes in a local economy due to the introduction of a new land use activity such as mining in this context (Rupasingha and Patrick 2009). The data of a smaller reference area (district) in an industry is rationed with same industry in a larger reference area (Region). Following is the equation used to compute the LQ using employment data of all districts. An LQ < 1 means that an area is less specialised in an industry (i) and might not be producing sufficiently to satisfy local demand of the products of that industry. Implicitly, the deficit may have to be obtained from outside the district. For example, although agriculture is the dominant economic activity in sub-Saharan Africa, it is found that countries in this region are net importers of food items from other countries to supplement local production (Yaro 2010; Mclntyre et al. 2009). An LQ = 1 means that an area could be more specialised in a particular industry (j) but only on subsistent basis. Areas that have an LQ>1 are more specialised in that activity and could be producing on commercial purposes. That is the ability to satisfy internal and external needs of the products of the particular industry.

2.5.2 Location association (La) model

The location association method was used to establish the spatial distribution and linkage between pairs of industry types in the study area. This measures the degree to which these industries have a location attraction for each other. Thus, a displacement of one industry indirectly affects the survival of the other. In this technique, employment data is mostly used to calculate the percentage value of each industry of a pair, say A/B, in each sub-location within the study area. Then B is subtracted from A (A-B) for each sub-location and the absolute values are summed, divided by 2 and the result is subtracted from 100. The value of the **La** varies from 0-100. The higher the **La** of any pair of industries, the stronger the spatial congruence and association between the pair in the area. Usually, a value greater than 60 is required to establish there is a strong relations between industries (Wei 2006; Feng and Ji 2011). Conversely, a **La** less than 50 indicates a weak spatial attraction between the pair. This implies that the introduction of one land use activity can have a negative impact on the other in a given geographic location.

2.5.3 Input-Output model (I-O)

Input-Output (Leontief) Model was used to analyse the means of location association between pairs of industries in all districts and villages. That is, the causes of attraction between (inter-dependence) between livelihood activities. Through this, a matrix of linkages of livelihood activities explains how modifications upon one activity can affect other activities in the same locality because of the exchange of goods and means of production between them. It also explains how changes in the industrial activities of one district A can affect changes in the activities of other districts B linked to A (Leontief 1987; Isard 1951). For instance, the displacement of tree cover by the mining sector would affect charcoal production and Shea picking, which would in turn affect charcoal vending and Shea butter production; the displacement of trees would affect honey bee keepers and for that matter honey and wax traders in the local market. However, a shortcoming of this model is that it is unable to stand alone to give a holistic visual impression of the magnitude and direction of anticipated changes in an economy (Stimson, Stough and Roberts 2006). Thus, the I-O model is usually combined with the LQ and La to describe the spatial relations between economic activities in an area (Stimson, Stough and Roberts 2006).

2.5.4 Land degradation and water stress impact analysis

The land degradation impact index model developed by Nachtergaele et al. (2010) in the Global Land Degradation Information System (GLADIS) was adopted and used to quantify the impacts of potential mining-induced land degradation and water stress in this study. To measure these effects in each locality, the land degradation index is a ratio of unit area per industry activity, multiplied by the poverty and population levels in that locality. Areas with no population means no potential impact of land degradation. Same procedure is used to calculate the potential impact of mining-induced water stress on rural households. However, with this parameter, the water stress index model of Alcamo, Flörke, and Märker (2007) is adopted and used. It is the ratio of annual water availability and withdrawal. Both land degradation and water stress are assessed as having poverty dimensions, which informs the use of poverty indices to estimate the impact indices (Nachtergaele et al. 2010; Alcamo, Flörke and Märker 2007). Digital Elevation Model (DEM) and Satellite imagery of the area were downloaded from USGS earth explorer. These data were used to develop the stream network, drainage basins, land use and land cover features of the area for analysing the potential effects of exploration and mining on water stress, land degradation and resettlement.

2.6 Discussions

With the adoption of the decentralisation system in Ghana in 1988, assemblymen have increasingly become very important stakeholders to rural decision making and development process. Therefore, access to community must first receive the support of the assemblymen before proceeding to the opinion leaders and Chiefs. In addition, there are a growing number of youth associations in the communities, who meet to deliberate and discuss the future of the communities in respect of development agenda and prospects. The strength of these groups must also be recognised in resource development issues.

The fieldwork offered local communities the opportunity to interact with their environment and its resource banks, in-situ, by being involved in mapping and at the same time discussing the mapped resources and environment. Village members had the opportunity to analyse their own environment and land use practices. Thus, it enabled them to gain a better understanding of the spatial organisation of the area so as to make rational decision in the use of resources and to identify appropriate practices and technologies that are compatible with their land objectives. This gives a sense of community empowerment and will help in stakeholder discussions. Some members were curious to have their entitlements captured on the maps. This, in turn, improves the sense of ownership and empowerment by rural communities.

One objective of the field data collection was to elicit communities' reactions in respect of on-going exploration activities and upcoming mine operations (Buckles and Rusnak 1999). This was achieved at the community entry phase. Some villages rejected the research and data collection activities based on the perception that the research will inure to the benefit of the exploration companies as against their interest. This event supports the assertion that resistance against the mining sector activities, in communities without previous mining experiences, is due to perceived threats of the industry to local livelihood. Overall, there was a high level community participation, contrary to earlier reactions and prejudice from some villages. To an extent that on most occasions, village Chiefs spent important part of their busy schedules on the fieldwork activities just to make meaning out of it. This is promising for negotiating resource development potentials in the area. During fieldwork, it was discovered that communities' muteness over exploration and preparations for large-scale mine operation is a strategy for a future aggregate response.

Scientifically, the study addressed important issues relating to mining land use and livelihood disarticulation. For instance, Cernea (2003a) identifies that when discussing compensation schemes associated with displacement, focus is usually on agriculture without recognition of other livelihood activities that are associated with space for input and output (I-O). Schueler, Kuemmerle, and Schröder (2011) further identified a challenge on linking the displacement of the socioeconomic activities of communities with mining land use. Such challenges misinform the implementation of alternative livelihood (AL) initiatives for resettlement of displaced communities (Hilson and Banchirigah 2009). An integration of the economic and spatial analysis techniques used in this research efficiently gave a recognition to the array of local activities potentially affected by an emerging mining sector.

The techniques have an advantage of identifying the importance of agricultural and non-agricultural livelihood activities in a local production system. This gives a comprehensive impression of the appropriate compensation and alternative livelihood schemes to deploy from one local area to another. For example, the location quotient (LQ) method established that other than agriculture, rural communities have varied economies that determine the culture and lifestyle of the people through successive seasons. Also, the location association (LA) and I-O methods show the links between an agrarian space and the diversity of livelihood such that, the direct mining sector impacts on one indirectly affects a chain of other sectors and could be a recipe for resistance and conflicts.

The PRA techniques proved efficient for generating non-existing village-level spatial data in developing countries. For instance, an integration of the PRA and GIS tools was useful in answering the questions: "How much local space is under exploration and mining tenements?", "How much agricultural land would potentially be displaced?" and "What minimum number of trees could be economically removed?" The absence of such measurements is an affront to efficient communication and negotiations between local communities and companies. Thus, the methods provided empowerment and escrow trajectories to local communities for engaging secondary stakeholders in mineral resource development.

During community entry, Focus Group Discussions (FGDs) and mapping, the views and sentiments of local communities against the emerging mining sector activities were collated. Detailed micro-level information that could not have been captured by remote sensing tools, such as satellite imagery, were accessed. This gives meaning to local space and latent conflicts identification prior to mine commissioning. However, satellite image analysis algorithms used in this study made it possible to compare historical spatial trends and patterns necessary for predicting the potential contribution of mining to future space and livelihood conditions. The satellite imagery and Digital Elevation Model (DEM) classifications were also useful in providing evidence of the landscape development opportunities and risks in a regional perspective. As such, it was possible to obtain and compare data of inaccessible areas and also to identify potential conflict hot-spots. Thus, the use of systems engineering approaches proved to be a useful means of analysing the functional weaknesses and gaps in the existing conflict management mechanisms and socioeconomic and environmental impact assessment methods. Although communities can express their opposition to exploration and mining activities without a spatial knowledge-base, their concerns cannot be evidently addressed.

Moreover, the application of spatial analysis tools to delineate the study area into potential impact sub-regions was innovative and a promising way of standardising impact assessments in remote areas of the mining sector activities. Rather than serving as substitutes, the models and maps generated from these analyses can fill the gaps of standard models for approving and granting exploration and mining leases in the area. For instance, the analysis showed that linking the models used in this study with GIS and remote sensing data can provide efficient measures of potential socioeconomic and environmental impacts and conflict locations in a regional perspective. The study area is absolutely new to mining activities, devoid of existing benchmarks and detailed environmental impact assessments of existing land use activities. Therefore, the delineation of the region into potential impact compartments offer a timely opportunity to fill these gaps and build harmonised geospatial data for land use planning.

Another major advantage of the PRA method is that community groups often learn to rely on more deliberative and well informed members (Kidd and Parshall 2000; Chambers 1994). The method has an advantage of dissolving entrenched positions often adopted by local community members on resource management and land use issues. However, a limitation of the research method is that it is time consuming and labour intensive. To address this challenge, the researcher guided over all group discussions; clarifying issues, reiterating objectives, and coordinating analysis for proper time management and labour saving. Furthermore, the PRA tools used in the data collection are generally criticised as being researcher-centred and exploitative of local knowledge (Chambers 2006). To address this shortcoming, the study has partnered with the district assemblies and other local area development organisations such as the Savannah Accelerated Development Authority (SADA) to take stock of the data generated during fieldwork and the results of the study for implementation. SADA has a geospatial unit that can use the spatial database of this study to implement the findings of the research. Importantly, SADA has a mandate to oversee the mining sector development in the study area and will, therefore, have the participation of local communities and district assemblies during implementation.

Also, the use of normalised units to calculate agricultural lands could be over simplified. There could exist abandoned farmlands in most of the communities. Besides, during fieldwork it was observed that there are little patches of tree groves and ponds that are not used for agricultural purposes. However, such features were generally acknowledged as sacred sites of communities. The trespass of exploration activities on these sites can lead to conflicts. Hence, it was deemed necessary to consider them as occupancies of local communities.

In the study country, Ghana, the approval rate of mining concessions is 100%; subject to the outcome of feasibility studies and mineralization (Obara and Jenkins 2006; Schueler, Kuemmerle and Schröder 2011; Minerals Commission 2010). Government does not hesitate in approving applications so long as these are proven to be viable. Thus, exploration and mining activities in the country are marked to increase in the country, even into previously inaccessible areas such as the study region. This estimation has been given due to the increasing approval rate and numbers of exploration and mining concessions (Obara and Jenkins 2006; Ghana Chamber of Mines 2013; Washbourne 2014). The exploration and mining company in the study area further affirms this assertion by stating on its 2016 mid-year reports that it has improved on its recovery rate and a new mining concession has been granted at the Mangwe EL in 2016 (Australia PayDirt 2016). That is, in less than 7 years after the first approvals.

2.7 Conclusions

Field activities included orientation and ground preparation, reconnaissance and site familiarisation, participatory field mapping and community resource inventory; transect walk and data geo-referencing, as well as data validation and corrections. Multi scale data generated by earlier research works in the area have been obtained for further problem specific analysis, observation, guidance, and validation. These include bio-physical and socioeconomic data obtained from various sources among which are academic and research institutions, as well as public and private organisations.

Though, the fieldwork was not meant to teach local communities new technologies developed for resource management in their environment, yet it provoked their quest for understanding the natural resource base of the area. This is a tool which will enable them, through participatory approaches, to analyse their own land use patterns and identify possible solutions and potentials for development. Besides, the field work was able to generate its own land resource and other spatial database of the area. Data of this sort are generally non-existent in resource-rich developing countries(Africa Mining Vision 2009). In particular, the fieldwork illustrates how critical a quantitative regional study is as a first step in assessing rural spatial organisation for multi-objective production systems. It also shows how such an assessment enables the assemblage of appropriate tools for targeted district and community level research. It can explore the drivers of land use conflict risks and management at the local-scale of mine development for which detailed data may be lacking.

Moreover, the fieldwork highlights the value of initial broad-scale local resource inventory as the starting point for more detailed, multi-method, multi-objective suitability analyses of rural space in Geographic Information Systems (GIS). This sort of innovative application of geo-spatial technology for natural resource management in developing countries has been widely called for across the mining and mineral resource development literature as well as states' resource management policies and initiatives (DFID 2005; Amanor et al. 2005; Union 2009; Mitchell 2006b).

Finally, the economic base models used, especially the LQ method, could be interpreted to mean that some local communities and districts are export oriented in agricultural production. This does not represent the realities of the villages. Although these areas supply most of the grains, cereals and biofuels to the urban markets, production is basically subsistence. Besides, using employment figures in this method does not necessarily reflect consistent production levels. For example, over 90% of rural households in the study area engage in agriculture, yet insufficient food supplies are recorded in these areas. This discrepancy is due to physical features such as depreciating soil fertility, reducing rainfall patterns and lack of farming incentives. However, the methods expose the magnitude of the impact of potential livelihood displacements and their cumulative effects on a regional scale.

CHAPTER 3 Mining and Agricultural Land Use at the District Level

This chapter is covered by the following conference publication:

Moomen, A.W., and A. Dewan. 2015. "Mining, agricultural space and land use conflicts: The role of local government." Agro-Geoinformatics (Agro-geoinformatics), 2015 Fourth International Conference on, 20-24 July 2015. DOI: 10.1109/Agro-Geoinformatics.2015.7248103. IEEE Xplore.

In both developed and developing mineral resource-rich countries, land provides the major source of rural livelihood, which is agriculture (Kiers et al. 2008; Coxhead and Warr 1995). Coincidentally, mineral resource sector development is also a rural phenomenon (Hilson 2002). Both agriculture and mining mostly require large tracts of rural land, although agricultural land use is more than that of the mining sector. Consequently, mineral resource development projects are often resisted due to a perceived displacement of agriculture in the countryside (Struck 1975; Cuba et al. 2014; Resosudarmo et al. 2009; Hintjens 2000). Hence, in this chapter, the spatial interactions between mining interests and agricultural space is quantified and analysed. The spatial analysis tools largely used include the location quotient (LQ) model and Geographic Information Systems (GIS). GIS overlay has been employed to normalize and quantify the various land use interests.

The LQ model has also been used to: (i) measure the importance of agriculture in the area, and (ii) predict changes in the local economy due to the introduction of a new land use activity such as mining in this context (Rupasingha and Patrick 2009). The LQ model calculates indices of relative specialisation of communities in the districts in agriculture as a livelihood activity. Employment data are often used; that is the number of households engaged in agriculture, or an agricultural activity such as crop farming and livestock keeping. This helps to determine the number of people potentially displaced per unit land displacement. A district with LQ>1 has more household engaged in agriculture (specialised) as compared to the number of households engaged in the activity in the upper west region. In this case, agricultural households could be producing more than they require to consume in a year. Thus, more households could be engaged in the activity because of its economic value. An example is the cocoa producing communities in the forest belt of Ghana. Almost all households in these areas own cocoa farms, and cocoa is a cash crop. Also, the farming communities in the northern savannah regions of Ghana provide most of the livestock and grain needs of the country (Abdou 2012). Hence, a displacement of crop land or pasture land would have a negative impact on the people engaged in these activities.

A district with LQ<1 has less households engaged in agriculture (less specialised) as compared to the number of households engaged in agriculture in the region. In the study area, factors that could account for this phenomena include: (i) less incentives, such as capital and market for agricultural products, to go into agriculture, and (ii) lack of suitable agricultural lands (Adu 2003; Ellis 2000) Thus, a displacement of land from the few households that are engaged in the activity would further discourage practice of the activity in the area. Further, a displacement of agriculturally suitable lands would result in a redundancy of more agricultural households than available space for production; that would lead to food security and unemployment issues.

The upper and lower limits of impacts used across various chapters are determined by the population data used in a particular analysis. For instance, analysis of crop farmers potentially displaced show the number of crop farmers with respect to spatial variations of number of people engaged in crop farming across districts and villages. There would be 12 people engaged in crop farming in one district, while another 300 people would engage in the same activity in a different district. The limits take care of the minimum and maximum number of people involved in the activity between districts and villages evaluated.

Mining, Agricultural Space and Land use Conflicts: the Role of local Government

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***Abstract*—Particularly in rural areas, where agriculture is a predominant livelihood activity and land use planning is either non-existent or poorly understood, local governments are unable to generate information for policy decisions in the mining sector. This makes local governments planning ineffective at addressing mining and agriculture land use displacement issues. This study quantifies the potential displacement of the agriculture industry activities by the activities of the mining industry on rural space. It also discusses the role of local governments planning and management strategies for mining related land use conflicts in rural areas. For this purpose, a case study has been conducted in the emerging Ghana's north-west gold province. Participatory Rural Appraisal (PRA) tools, the economic base model, and geospatial tools have been integrated and used in GIS. The study finds that agricultural production in the districts just suffices local demand and insufficient for export. Apart from the potential displacement of cultivable lands and pastures by exploration and mining activities, the evidence also suggests a potential displacement of crop farmers and livestock in affected communities. In the wake of mining and exploration activities, district assemblies are expected to extend their coordinating role between economic diversification, food security and land use conflicts. The study's findings will enhance benchmark indicators for removing tensions and risk uncertainties associated with mining and exploration activities in the districts.**

Keywords—Mining, Agriculture, land use, conflicts, rural

I. INTRODUCTION

Mineral resource extraction is recognized as an asset for economic growth and rural livelihood improvement in mineral-rich developing countries. The prospects of developing these assets creates resistances and land use conflicts between the industry and local communities. These require a strategic attention from research and the local government sector. The vision of the 'New Natural Resource Policy Agenda' coordinated by the World Bank considered decentralization of government as a vital mechanism to addressing the phenomenon of mining related land use issues in developing countries [1, 2]. Inspite of the advancement of this policy, new land use conflicts continue to emerge in these areas. The spatial relationship between mining and agriculture can always be assessed before new projects are granted.

Resistance to the mining industry activities is driven in part by the perceived threat it poses to the agriculture industry in local communities. These concerns always remain unaddressed and are a development challenge for the local government sector on their economic diversification prospections. Developing countries have recognized the importance of economic diversification to the sustainability of local economies [3]. Agriculture, Mining, and Tourism industries have the collective potentials to obtain this economic diversity [3-5]. However, mining and agricultural land use objectives are often not incorporated in the spatial and development planning of local governments.

The challenge for geographical research to develop framework for harnessing the benefits of the two important industries have focused on the displacement impacts of the mining industry on agriculture during and after mine commissioning [6-8]. It is rather critical that baseline analysis be carried out to quantify, predict and address the potential socioeconomic and community impacts before new projects are commissioned. Nevertheless, no such studies have often been undertaken to inform local governments of the desired role they have to play to manage these potential conflicts in advance. Besides, local governments generally have no upfront understanding of the changes that the interactions of mining and agricultural activities will bring on livelihood.

The purpose of this paper is to provide baseline information about basic indicators of the spatial interaction between agriculture and the mining industry. This paper pursues to: (a) quantify and assess the potential displacements exploration and mining activities have on agriculture at a district wide perspective; (b) evaluate and predict the potential impacts and associated land use conflicts and; (c) formulate research-based recommendations to district assemblies on their roles to effectively manage land use conflicts in the resources sector.

II. METHODS

A. Study Area

In the context of minerals and mining success profile in Africa, Ghana is a lead model. Ghana is the leading gold producer in West Africa, second in Africa, and about the tenth in the world [9, 10] (Fig. 1). The country is also a significant producer of aluminium, manganese ore, bauxite and diamond [11].

The fieldwork and data collection component of this research has been co-funded by the Crawford Fund and International Mining for Development Centre (IM4DC) with support from WASM director

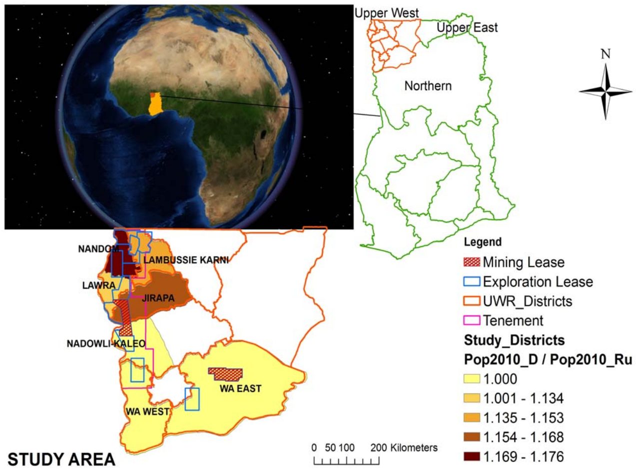

Fig. 1 Study Area

Deposits of Uranium and Copper are recent discoveries and further exploratory works are still going on in many parts of the country. Historically, Ghana's mining activities are based in the southern parts of the country. However, there have been recent discoveries of gold deposits in Northern, Upper East and Upper West regions in the north of the country. Agriculture is the traditional livelihood activity and sustainer of the economy in this area. Inspite of several interventions in the past three decades, production levels in the agriculture sector has not been encouraging and poverty is pervasive [4, 5, 12]. On this basis, this paper focuses on a case study in the Upper West Region (UWR) of Ghana (Fig.1).

UWR has a population of 702, 110 with high densities occurring in the western corridor [13]. This has adverse implications on land use. The area has been under mineral resource exploration since 1940s [14] and recent recoveries of viable quantities have given it a name: "the Emerging Ghana's North-west Gold Province" [15]. Ghana has a unique local government system referred to as the District Assembly system. The study focuses on seven of eleven districts currently under prospection, exploration and mining leases in the UWR.

B. Data Collection

Land suitability map for Agriculture and Forestry was obtained from the Soil Research Institute (SRI) at a scale 1:250,000. This map covers the entire Wa-Lawra belt and was digitized. It was validated at 1km x 1km north and south, east and west transects during fieldwork, to re-inforce data accuracy. Tenement, Prospecting Lease (PL) and Exploration Lease (EL) maps granted in the study area have been digitized from Azumah Resources Pty Ltd reports. District point and polygon shape files, socioeconomic database; Number of Households (Nhh) engaged in Agriculture in each district; population data per district for the 2010 Population and Housing Census (PHC 2010) have all been obtained from the Ghana Statistical Service (GSS) and used in analysis. Polygon layers of state lands including forest reserves have also been obtained from the GIS laboratory of the Geography and Resource Development Department, University of Ghana (UG). Data for food crop production levels were obtained from the District Agriculture Divisional Units (DADU) and assemblies. The production levels have been calculated in Metric Tons (Mt) per Hector (ha). Available data for all districts were from 2003 to 2010. But we could not decipher between production levels where manure or fertilizer was used on farmlands and those of natural rigour. Consent and support was obtained from the Regional House of Chiefs and all District Assemblies.

C. Analysis and Conflict Risks Mapping

1) Coefficient of Specialisation in the Production system

The Location Quotient (LQ) technique of the economic base model was used to determine if agriculture as an industry is practiced mainly on subsistence (Non-Basic) or was oriented to the markets (Basic). The technique uses the Number of Households (Nhh) engaged in the agriculture industry in each district as a ratio to total employment in all industry types and compares with the ratio of the number of households engaged in agriculture at a regional scale and the entire employment figures of all industry types in the region. In Ghana, the major agricultural activities include crop farming, livestock keeping, fishing, and tree planting. Thus, the LQ of the above types of agricultural activities have been calculated as well. The following is the equation of the LQ technique used:

$$\text{Location Quotient (LQ)} = [(E_{ijt} / E_{jt}) / (E_{iJt} / E_{Jt})] \quad (1)$$

E = Employment i = industry j = district t = time
J = Region LQ < 1; (non_basic); LQ = 1; (non_basic);
LQ > 1; (Basic)

2) Normalized Units/Life cycle thinking

a) Crop farmers Potential Displacement

The normalized units and life cycle thinking approaches [16, 17] were also used to estimate the extent of potential spatial displacement of each agricultural activity under exploration and mining leases in each district. These have been shown as potentially displaced cultivable lands, pasture, and livestock. Cultivable lands are measured by spatially joining state lands (forest reserves) and district maps. The area of intersection of state lands and district map was calculated and subtracted from the district map area. Available cultivable lands were calculated by spatially joining total area of district cultivable lands with unsuitable agriculture and forestry lands. The area of intersection of the spatial join between the two polygons was then calculated and subtracted from district cultivable lands. Then, the unsuitable agriculture and forestry lands polygons were spatially joined with the Exploration Leases (EL) maps. The area of intersection was calculated and taken from the EL area to generate EL actual. Finally, the EL actual area was calculated and also taken from the cultivable lands to get the Available Cultivable lands. Below are the equations used:

$$\text{Avail\_Cultivable\_lands: (Cultivable lands}_{jt} - \text{EL}_{actual(jt)}) \quad (2)$$

But, Cultivable lands: Total area A of district (j) less unsuitable Agriculture and Forestry lands (AFu)

$$\text{Cultivable lands} = T_{Aj} – AFu_{Aj} \quad (3)$$

And EL actual: Area A of Exploration Lease (EL) on Cultivable lands less area of exploration lease (EL) intersection unsuitable Agriculture and Forestry lands (AFu)

$$EL_{actual} = EL_{Aj} – (EL_{Aj} \cap AFu_{Aj}) \quad (4)$$

$$\text{Displacement } (–S) = NhhCropF2_{jt} – NhhCropF1_{jt} \quad (5)$$

$$\text{But, } NhhCropF2_{jt} = [(NhhCropF1_{jt}) \times (2) / (3)] \quad (6)$$

$NhhCropF1_{jt}$ = Number of Households in Crop Farming before EL was granted and NhhCropF2 = after EL has been granted. Negative indicates potential displacement and positive means no potential displacement.

b) Cereal Crops Potential Displacement

The major cereal crops cultivated in the study area are: Maize, Millet, Sorghum, Soybeans, Cowpea, Rice and Groundnuts [14, 18]. The average yield per hectare (ha) was calculated using the annual average yield of crops within the period for which data was available in each district. Potential crop loss in Metric tons (Mt) was estimated using the following equation:

$$CL_j = AACY_j \times (4) \quad (7)$$

CL: Crop Loss and AACY: Annual Average Crop Yield.

c) Herbivorous Livestock Potential Displacement

The potential displacement of Forage Dry Matter (FDM) and its impact on livestock was estimated using livestock census figures from the PHC 2010. The following equations were used: t is 365 days

$$NHLReqFDM_{jt} = [(HLPop_{jt}) \times (FDM1_{jt}) / (9) \quad (8)$$

FDM per hectare (ha) in a year is given as 2170kg [19]. NHLReq: Number of Herbivorous Livestock required to exhaust available FDM in each location j (district) before EL was granted. Herbivorous Livestock potential displacement (NHL_{jt}_–S) is estimated by the following calculations:
$ATLUFC_t$: Average Tropical Livestock Unit Forage Consumption per day = 6.25kg[20].
$HLPop_{jt}$: Herbivorous Livestock Population.

Qu_Fora_{jt} = Quantity of forage required to feed available livestock in a year is:

$$Qu\_Fora_{jt} = 6.25kg \times (HLPop_{jt}) \times 365days \quad (9)$$

FDM1: FDM before EL was granted

$$FDM1_{jt} = 2170kg \times T_{Aj} \quad (10)$$

FDM2: after EL has been granted

$$\text{If } FDM2_{jt} = 2170kg \times (T_{Aj} – EL_{Aj}) \quad (11)$$

$$\text{Then } NHLReqFDM2_{jt} = [(HLPop_{jt}) \times (11) / (9)] \quad (12)$$

$$NHL_{jt}\_\text{-}S = (12) – (HLPop_{jt}) \quad (13)$$

III. RESULTS AND DISCUSSION

A. Coefficient of Specialisation in the Production system

The study used the LQ method to establish the degree of districts specialization in the agriculture industry. The LQ technique of the economic base model is most widely used due to its simplicity [21]. The technique helps to understand the existing patterns of the local economy and also be able to predict the impacts of potential changes on the economy and associated conflicts in the area. An LQ greater than one means that a local community is able to produce beyond the local demand of the agriculture sector (Fig. 2). Thus, a particular locality may be a major supplier of agricultural products to neighboring localities and beyond. However, an LQ equal to one indicates that a local community is able to meet its local demand of the agricultural products and cannot supply to other localities. An LQ less than one implies that the local area is unable to meet its local demand of grain and meat let alone to supply to other areas (Fig 3). Such locality may be a net importer of agricultural products from her neighbors. This is where we draw the line to potential resistance.

In any case, an amount of productive agricultural land that may be taken from communities with an LQ equal to or less than one would further destabilize livelihoods. The results in Fig. 2 reveal that four out of seven districts have LQ greater than one. Only one district has an LQ equal to one with the other two having LQs below one.

This gives an insight into land use conflict hot spots. The hot spots are those districts that are unable to meet the local demand of agricultural products while living on intact cultivable and pasture lands for several decades.

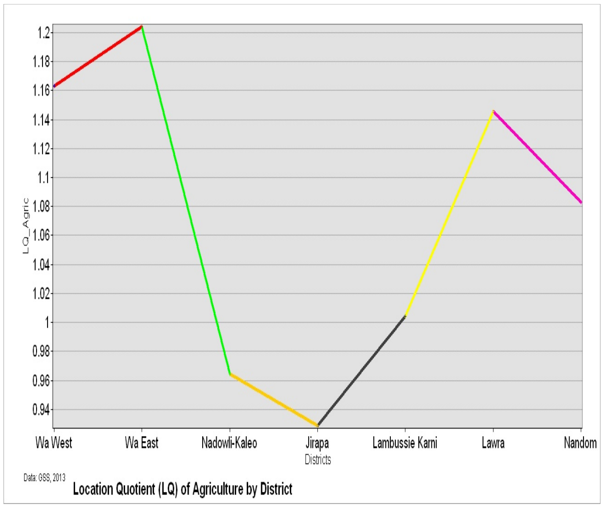

Fig. 2 Location Quotient (LQ) of Agriculture by districts

Conversely, local areas or neighboring districts that previously had demand for the supplies of agricultural products from affected districts could look elsewhere in earnest for substitute. There is a conflict risk where the demand for food products at location A cannot be matched with the ability to afford and the willingness to travel to a substitute supply center, location B. Fig. 3 shows the potentials of these tendencies. Conflicts could be predicted by identifying the thresholds of demand and supply between districts. However, it suffices to quantify the potential displacement and compare the impacts on the local space. That is the amount of land area potentially at the disposal of communities for crop cultivation after EL has been granted.

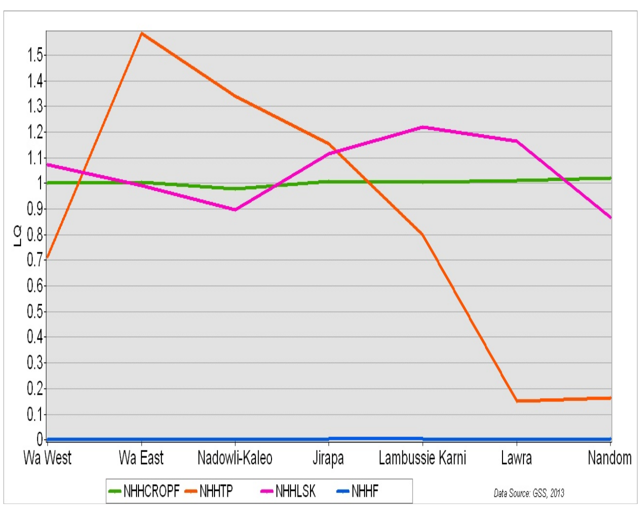

Fig. 3 Location Quotient (LQ) of Agriculture types by districts

B. Cultivable Lands and Farmers Potential Displacement

Once an exploration lease is granted in an area, local communities' rights to farm on these lands are curtailed [22]. Fig. 4 indicates areas that have been potentially displaced of cultivable lands and the corresponding number of households under threat of displacement are shown in Fig. 5.

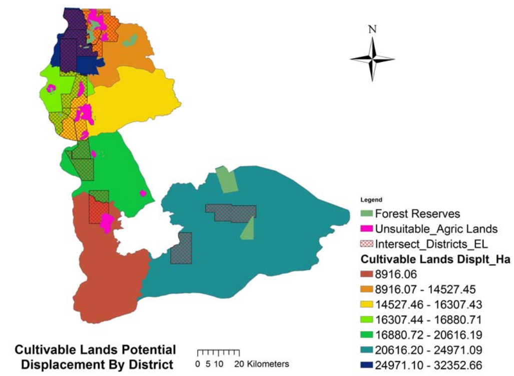

Fig. 4 Cultivable lands potential displacement measured in Hectares (Ha)

Dwellings and settlements have been secluded in the spatial analysis with cognizance to the farming systems practiced in the study area [18, 23]. These practices have made it impractical to separate cultivable lands from dwellings and settlements in the analysis.

A part from areas scientifically mapped as unsuitable for agriculture and forestry [14], all other aspects of the landscape are significant to agriculture. The results above highlight the conflict risks on croplands and farmers across the districts. Those risks can be addressed with local communities' participation in the process [16].

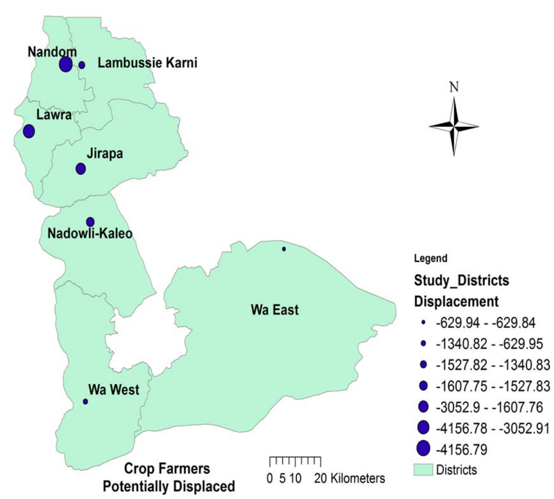

Fig. 5 Crop farmers potential displacement by district

C. Food Crop Potential Displacement

The potential cultivable lands displacements should correspond with associated food security uncertainties. We used the data of only cereal crops. Where there is zero, it means that particular crop may not or may be cultivated but in negligible quantities. For instance, from the results in fig. 6, potential loss of soybeans and rice reflect zero for the Nadowli-Kaleo district. However, we could not identify which district was more specialized in the crop type's production.

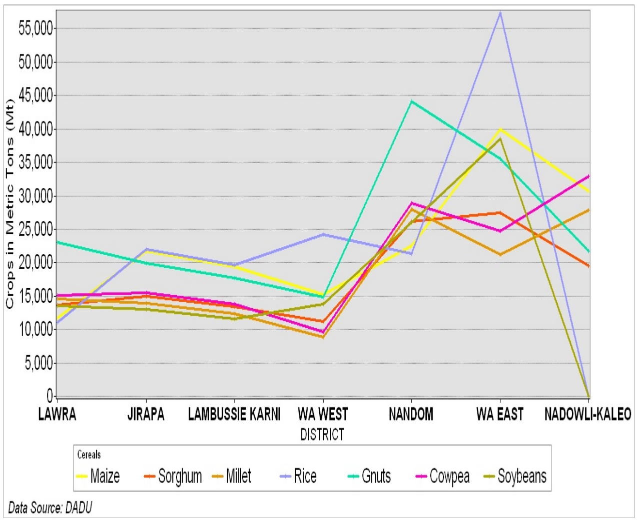

Fig. 6 Food crops potential displacement measured in Metric tons (Mt)

This is determined by a number of factors, including soil suitability, rainfall, fertility, demand and culture. Previous works in the area have shown that farmlands that have been manured yielded up to six tons per hectare of cereal. But unmanured farmlands yielded approximately 1.1 tons per hectare [18]. Displaced farmers are usually paid compensations based on the recommendations of the Lands Valuation Board (LVB). But, this compensation scheme is contested since the long term losses of farmers are usually not considered [24].

D. Herbivorous Livestock Potential Displacement

Livestock production is an important source of livelihood and income for many households in Sub-Saharan Africa [19, 20, 25]. In recent times, recommendations for improving farmland productivity and food security in most developing countries are the reintroduction of mixed farming [18]. This proposal re-emphasizes the significance of livestock keeping over the coming years. Contrary to the general statement that there is pasture shortage in the north of Ghana [23], the results in fig. 7 have shown that whereas some areas may experience deficits of FDM due to exploration and mining activities, other areas are in surpluses.

Herbivorous Livestock (HL) have unlimited access to pasture in the area. Animals are tethered during cropping season and are released to free range in the rest of the year. The whole landscape is a potential for grazing. Animals are also fed with 'cut and carry' system. That is where forage is cut in the bush and carried to homes for animals to feed.

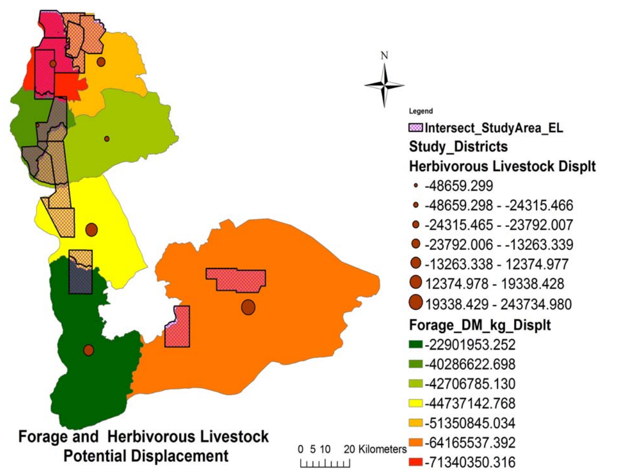

Fig. 7 Forage in kilograms (kg)/Herbivorous Livestock potential displacement

Seasonal inland water systems have not been taken out when calculating cultivable and pasture lands potential displacement. During the dry seasons, streams dry up leaving behind remnants of herbs on which wandering animals feed. Besides, streams and dams with little water in them during off seasons are used to support small scale garden activities a part from serving as source of drinking water for livestock. On this basis, inland water systems are considered as agriculturally valuable [26].

IV. THE EXPECTED ROLE OF LOCAL GOVERNMENTS/DISTRICT ASSEMBLIES

Confronted by mineral exploration and mining development issues, it is expected that local governments should coordinate between harnessing the full potentials of their resources whilst at the same time preserving the existing local livelihood structures [27, 28]. To do this, district assemblies should do a region wide analysis of the potential effects of new mineral resource development on the basic economic sectors of communities. Since local communities are interlinked by social and economic ties [29], it is possible to identify the thresholds of potential economic displacements and land use conflicts at the early stages of exploration.

District assemblies should be able to link up and incorporate the development plans of the mining industry and that of the agriculture industry. By doing this, a comprehensive regional plan can be developed. This can accommodate the land use interests of local communities and that of the mining industry for an enhanced economic futures.

District assemblies should collaborate with local academic institutions that can support them build a geospatial database of spatio–economic thresholds at both district and village scale. This would help build a common knowledge base, information sharing capacity and empower locals to engage in meaningful negotiations rather than violent conflicts.

District assemblies have to play a proactive role, having equipped with the foregoing, by engaging both central government and junior companies in meaningful negotiation deals prior to mine development. On this, critical issues such as Agricultural Impact Assessments can be addressed intuitively rather than policing.

V. CONCLUSIONS

We quantified and visualized the potential displacements of the agriculture industry by the activities of the mining industry. The constitutional barriers in most developing countries that challenge local governments' full participation in the decision making processes of exploration and concession lease granting cannot be neglected. Nonetheless, prospects exist for local governments and district assemblies to collaborate with local research and academic institutions that have Geo-Spatial research Units. Through such schemes, it is possible to unearth necessary information and knowledge for mitigating or reducing land use conflicts between local communities and the mining industry. Otherwise, districts remain at a fork-head of rural livelihood management: to barter between agriculture industry coupled with low farm yields, livestock infestation; or mining activities with associated farmland and pasture displacement; or mining activities where rural women have no job share. To find a framework that makes it possible for the peaceful co-existence of these two important growth and economic drivers is a necessity. Our study largely looks into the modalities for developing such a model that enhances the measurement, quantification, prediction and management of land use conflicts between the mining industry and local communities in developing countries.

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CHAPTER 4 Mining, Agricultural and Non-Agricultural Land Uses at the Village Level

Chapter 4 is covered by the following publication:

Moomen, A.W. 2015. "Quantifying Potential Socioeconomic Displacements and Land-use Conflicts in Prospective Mining Villages in Ghana." WSEAS Transactions on Environment and Development, Volume 11, 2015, Art. #35, pp. 325-342

This chapter is an in-depth study of chapter three. In this chapter, the land occupancy maps of sampled communities have been developed, through fieldwork, and used to analyse the potential displacement of agricultural space and conflicts between the communities and, exploration and mining companies. Hereafter, the chapter identifies and measures non-agricultural livelihood activities in the local communities. The spatial interaction between non-agricultural rural livelihood activities and mining leases is visualised to show potential displacements. A special focus is given to the Shea industry as the most dominant non-agricultural livelihood in tropical sub-Saharan Africa (Schreckenberg et al. 2006).

Mining leads to the removal of trees that have both economic and medicinal value to local communities. In particular, this chapter analyses the potential impact of the Shea tree displacement and its economic effects on women since the Shea industry is female dominated (Pouliot 2012). Few studies have discussed the displacement of economic trees and the impacts on women. Thus, it is argued that women are mostly marginalised when it comes to compensation and land use issues in most mineral-rich developing countries (Akabzaa and Darimani 2001; Human Rights Clinic 2010).

Similar to Chapter three, the spatial analysis tools used in this chapter include the location quotient (LQ) and location association (La) models and GIS overlay. The La model analyses the likelihood that the occurrence of agriculture as a dominant livelihood activity in a village would lead to the practice of local manufacturing, such as beverage brewing, in the same village or nearby village. Like the LQ model, the La also uses employment data to reflect the indirect employment implications associated with the displacement of one land use activity on other people. Whereas the LQ considers some direct implications, the La analyses the indirect implications by establishing the affinity between various sectors. Input-Output (I-O) illustrates this cross sector links using products of each sector and the requirements of other sectors for production. For instance, the inputs required to brew local beverages (manufacturing) include millet, which is obtained from crop farming (agriculture). Thus, more people would be attracted to brew near communities where access to millet would be considerable (the I-O model). A displacement of millet farms and farmers would result in an indirect displacement of the breweries. Hence, a connection between the La and I-O models establishes that displacement of cultivable lands would have an indirect effect on the manufacturing sector based on the level of interdependence between them.

For the reason that villages have both social and trade linkages with neighboring communities, indicators of socioeconomic displacement can provide efficient standards for addressing future cumulative impacts of the mining industry on rural livelihoods. For instance, the landscapes of some villages are suitable for yam production whereas others cannot. Through a common market at the village level, as is common in Africa, communities exchange or patronise food crops and other materials such as yam from those who have the suitable landscapes to produce these. However, a displacement of suitable yam cultivable lands would imply that the impacts would affect not only the yam producing villages but including those that also depend on them for yam. Yam is an important cultural food item, mostly required for paying bride prices of marriages in communities.

Hence, a responsibility lies on the District Assemblies to develop measures that would help coordinate between the economic futures of the local communities and their developmental needs. This requires a holistic understanding of the potential impacts of mining-induced displacement on both agricultural and non-agricultural livelihoods. Thus, the chapter following this chapter analyses the potential displacement of Shea trees and its impacts on the district populations.

Quantifying Potential Socioeconomic Displacements and Land Use Conflicts in Prospective Mining Villages in Ghana

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Abstract: - This study advances that quantifying the potential cost of the mining industry's activities on local communities' livelihood can be an efficient tool for managing company-community land use conflicts. A case study is conducted in the emerging Ghana's North-west gold province. The study combines and uses primary and secondary data that were obtained during two fieldworks. The livelihood activities of 55 sample villages were inventoried and characterised using techniques of regional science. Furthermore, Participatory Rural Appraisal (PRA) and Geographic Information Science (GIS) tools are integrated. These tools are used to develop land use extents base maps of 53 out of the 55 sample villages. The study finds agriculture, manufacturing, wholesale and retail as the major livelihood sectors in the communities. A coefficient of specialisation (LQ) > 1 in non-agricultural livelihood is found in over 75% of the villages; and a location association (La) > 50 between the industries. The study also quantifies the interactions between village space and mining land use interests. The minimum village area potentially displaced by exploration and mining leases is 90 ha, and the maximum is from 2861 to 4576 ha. Following the location association between industries, a displacement of villages' space will have a cumulative effect on major aspects of the local economy. The findings can enhance sustainable mining, local communities' empowerment, and benchmark indicators for land use conflicts management in Africa.

Key-words:-Village, mining, land-use, conflicts, displacement, livelihood, District

1 Introduction

Rural communities in Africa, over the past three decades, are experiencing environmental, social and economic transformations. These transformations are largely a result of the proliferation of mineral resource sector investments. The mineral resource industry is considered as an asset through which Africa's quest for industrialisation and development can be obtained [1]. However, the prospects of developing these assets are creating land use conflicts between local communities and the mining industry. The trends and patterns of the conflicts are increasing. Meanwhile, development of mechanisms for managing these conflicts has been a governance and international policy delusion. The needs and demand of African rural communities at present are food security, livelihood, and infrastructure [2]. Nevertheless, African governments assert that the current needs can be obtained through a reinvestment from the mineral resource sector [1]. It implies compromises of land, although, the economy of African rural communities is based on land resources and related industrial and commercial enterprises. Hence, it is evident in Africa that most violent conflicts are associated with mineral and other land resources [3]. To mitigate such conflicts, the potential impacts of mining on rural livelihood and rural land resources should be identified at the exploration stages [4].

Four fundamental causes of conflicts between communities and the industry have been identified. These range from the distribution of royalties, survival of small-scale mines, land use and resettlement [5]. Land use conflicts have been recognised as the most difficult to manage in corporate-community issues [6]. These have negative impacts on both communities and companies. For communities, land use conflicts may lead to stagnation of economic and social development. For the companies, conflicts with local communities have resulted in the temporary and sometimes permanent close down of projects [6, 7]. It is estimated that corporate-community conflicts have cost over 80% of management working time used in dispute negotiations [8]. It translates into US$ 20 million per week for an operating mine, and about US$ 10, 000 per day of an exploration company [8]. To manage these conflicts and the associated losses requires consultations and mediation tools [9].

Hilson [7] finds communication gap as a major factor in company-community conflicts. Lack of information and communication about the spatial extents and impacts of the industry's interests contribute to uncertainties, communities' anxiety and resistance. It also disempowers local communities from engaging companies and government in meaningful negotiations and mutual consultations. Communities need information about the extent of their land that has been leased to companies. Failure to get answers for their anxieties, tensions and uncertainties leap into violent conflicts [10]. However, most African countries lack spatial information and village maps for an efficient policy decision making and management of rural resources [11, 12]. As in many developing countries in Asia and Latin America, the mining sector policy in most African countries entrenches compulsory extraction of mineral resources [13, 14], whether beneath or above the land surface. It implies that while customary lands are recognised, traditional rights end where they conflict with national interests. As a result, decision makers grant new concessions without understanding the realities on the ground; considerations for the futures of rural livelihoods. Consequently, conflicts escalate when the industry's activities interfere with villages' land use activities.

Furthermore, the rural landscape transformations come at the back of sustainable development [15]; failing to recognise the heterogeneity of the traditional livelihood activities of African rural communities. Development of the mineral resource sector in Africa has the potential to engender the course of an integrated rural development [1]. Thus, resource development has given a new recognition of rural landscapes as multifunctional economic enclaves rather than been monopolistic agricultural landscapes [16]. However, mineral resource development requires large tracts of land, while, at the same time, agricultural production necessitates both arable and pasture lands. Moreover, in recent times, there is a growing need for mix-farming in rural landscapes in Africa. Crops and livestock co-production are encouraged for maximising agricultural output [17]. Besides, it is also identified that rural communities are diversifying livelihood activities, based on land resources, to improve their resilience against impoverishment [18]. Thus, an introduction to mineral resource development brings with it an incipient competition for productive land. As a consequence, there is a deepening growth of land use conflicts. To manage these conflicts between the mining industry and rural communities, the role of sustainable development must be recognised. Sustainable development processes require an analysis and quantification of competing socioeconomic activities in the landscape.

Nonetheless, no study has analysed and quantified the extent of land occupancy, and the potential impact of the mining industry's interests on the socioeconomic activities of rural communities. To this end, this paper aims to develop a framework that will enhance the availability and use of information for informed decision making on village resources. Specifically, the paper seeks to generate data to build a collective knowledge base that is accessible to all stakeholders. It also analyses the spatial interactions between company activities and local communities' socioeconomic activities. That is both agricultural and non-agricultural land use activities. The paper further assesses and predicts the impacts of new proposals on rural communities and potential conflicts. It will facilitate meaningful negotiations between all stakeholders in the mineral resource area. The next section discusses the materials and methods employed in the study. It is followed by detailed discussions of the results. The paper then concludes with a summary of the major activities and findings.

2 Materials and methods

2.1 Study Area

In the context of natural resource endowment and mineral resource development, in particular, Ghana is considered a benchmark indicator for resource-based development and industrialisation in Africa. The country's Medium Term Development Policy Framework aims to achieve a structural transformation of the economy through modernised agriculture and mineral resources [19]. Agriculture and mining contribute more than half of Ghana's Gross Domestic Products (GDP). The agriculture sector employs more than 60% of the labour force and over 80% of rural households [20]. Although progress in the non-agricultural sector of the economy is slow, it is gradually withdrawing labour from the agriculture sector [21]. For instance, the mining industry continues to grow with new approvals granted in areas that have not had mining sector experience before. It converts land from other uses into mineral resource exploration and extraction. Previously, mining sector activities were a Southern fringe land use phenomenon in Ghana. However, recent discoveries of viable quantities of mineral deposits in the three Northern regions of the country have given a different meaning to this phenomenon [22, 23].

Traditionally, the three regions of Northern Ghana's economy is primarily driven by agriculture. The sector employs over 90% of rural populations in these areas, which is mainly attributed to the poverty hikes in the area [24]. Hence, rural communities in the area are diversifying their livelihood opportunities from agriculture to off-farm and non-agricultural activities [25]. Diversified rural livelihood activities include petty trading, wood carving, gardening, and Shea-processing. A minimum of 95% of women in rural communities in the area is engaged in the Shea-processing industry [26]. DFID [27] find that agro-based industries and tourism hold the key to breaking poverty hikes in the three Northern regions. It however, reiterates that the requisite capital to support these industries to sustainable levels may flow from the mineral resource sector returns. Hence, it is worth developing a framework that can enhance a multi-sector production in the rural landscape. Thus, this study takes on the emerging Ghana's North-West Gold Province in the Upper West Region (UWR) (Fig. 1).

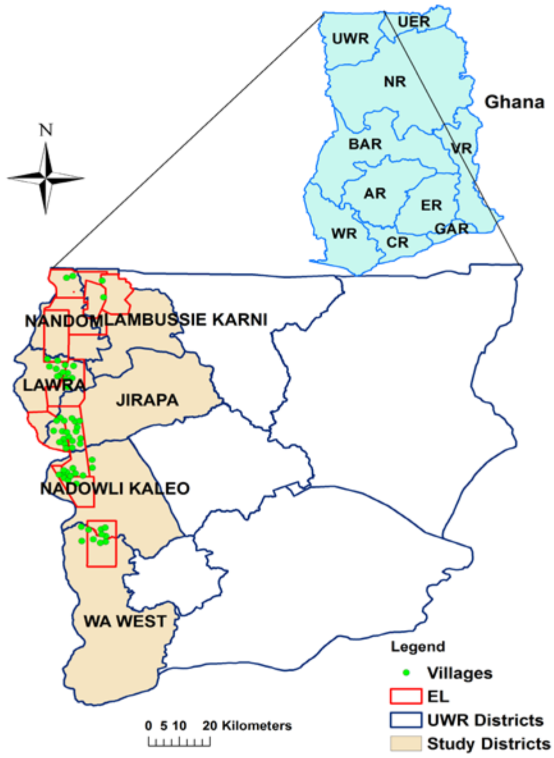

Fig. 1 Study Area

2.2 Data Collection and Preparations

As can be associated to developing countries, there is a lack of spatial data in Ghana, particularly in the rural level. Therefore, the data for this study were collected during fieldworks. Two field visits were done from December 2013 to February 2014; and December 2014 to February 2015. The objective of the fieldworks was to identify sample villages for the inventory of land use and livelihood activities. The names of these villages were then used for a purposive and cluster sampling of other communities in the exploration leases (ELs). Another objective was to map the spatial extents of land use activities across village space. The fieldworks were also an opportunity to source existing data, covering communities' physiological and socioeconomic activities. These objectives were pursued in three stages: community entry, data collection, and data validation. The purpose of the community entry was to explain the goals of the study to the District Assemblies (DAs), the sample villages and to seek their consent. Overall, the DAs and the communities supported the research. Also, under the decentralisation system, community development programs are channelled through the DAs. Assemblymen are members elected to represent the communities' development interests in the DAs.

Agriculture and Forest suitability map for the study area was obtained from the Soil Research Institute (SRI), Council for Scientific and Industrial Research (CSIR) of Ghana. The map has been developed by SRI based on extensive soil inventory and physiographic analysis of the landscape. Details of the survey methods used in developing the map can be found in Adu [28]. The agriculture and forest suitability map was uploaded and digitized in ArcMap. The digitized map was used together with the ELs and land use sketch maps of the villages to identify areas of high impact displacement.

The Centre for Remote Sensing and Geographic Information Services (CERSGIS) at the University of Ghana has developed a land cover scheme. The scheme has been prepared in conformity with the USGS land cover mapping system and used to produce a land cover map of Ghana. This system applies to all the agro-ecological zones of Ghana. Details of the algorithms used in developing the project can be found in Agyapong, et al. [29]. Land cover data generated from this project are obtained from the Department of Geography and Resource Development, University of Ghana, and used for tree density analysis in this study. The data is accompanied by numerical values of estimated tree densities per land cover type.

Digital map, containing shapefiles of all districts in the study area, is obtained from the Ghana Statistical Service (GSS). However, Nandom and Nadowli-Kaleo Districts are new Districts delineated from the former Lawra and Nadowli Districts. Thus, digital maps for the new Districts were not yet available at the time of fieldwork. Therefore, maps for these new Districts were digitized from historical maps of the former Districts. For the purposes of this study, the map digitizing was accomplished with the aid of local authorities.

2.2.1 Sampling

A multi-stage sampling technique was employed in this study. First, the company with exploration and mining interest in the study area was identified. The tenement map for exploration and mining activities was downloaded from the company’s website. The map is in the Universal Transverse Mercator (UTM) projection system. The exploration leases together with drill-holes in the tenement map were uploaded onto ArcMap and digitized. In this connection, the assemblymen of lead villages helped to identify further other communities within same EL and also an electoral area in the district assembly system. The sampling was pruned down to villages that share kinship ties and economic space with the lead communities. The lead villages are those that contain drill holes and are also used by companies to name ELs. The purpose of these criteria used is that land is communally owned and managed by kinship ties among the tribes in the area. Issues relating to land in one community affects a host of other communities otherwise not considered as mining communities [30].

Overall, 55 villages have been sampled from five Districts. The communities are Bulituo, Eggu, Oli, Sukpare, and Zan in the Wa West District. Berendari, Butele, Gabilee, Konne, Musama, Mwindaale, Nanga-Wuchema, Niiri, Sabiili, Tangasia, Tanduori, Turi-Dari, Vuuyiri, Yaro, and Yiziri in Nadowli-Kaleo district. Gbetuol, Guoripuo, Kakala, Kul-Ora, Kpannyaga, Kunzokala, Orifane, Tambore, Tampoe, Tanzire, Tikpe, Tie, Tuolung, Wuling, Yagha-Baapari, Yagha-Gbaani, Yagha-Kusoglo, and Yagha-Tohaa in Jirapa District. The rest are Bompari, Buree, Danko, Dazuuri Baapari, Dazuuri Dabozeri, Nayiribog, Naburnye, Toto, Sorgoun, Yagra, Yagra Tangzu, and Zinpen in the Lawra District. Kokoligu, and Kokoligu Gbantakuri in Nandom District; Banwon and Billaw in Lambussie Karni District. However, fieldwork was completed in all the villages except the Kokoligu and Kokoligu Gbantakuri in Nandom District. It was due to challenges in accessing the community.

2.2.2 Focus group discussions and Participatory Mapping

In each village, leaders and village groups were identified and invited to participate voluntarily in focus group discussions and participatory mapping activities. Identifiable individuals and groups were village chiefs, priests, community youth association, village unit committee, and women association. Other village experts such as experienced farmers and hunters were also engaged in the focus group and sketch mapping. These individuals and groups have knowledge about the villages' development objectives and land use patterns. There was at least one representative from each of these groups making a maximum of 10 participants in each focus group and participatory mapping session in each village. The sessions lasted for a maximum of 5 hours and a minimum of 3 hours. In total, 53 meetings were held with a maximum of 530 participants in the field data collection activities. Examples of discussions questions are: "Which livelihood opportunities exist in the village? In respect of animals, plant materials, rock minerals, and soils harvested for food, clothing, medicines, sacrifice; shelter, tools, and rent". "How much land area is used or occupied by existing and previous livelihood activities in the village landscape"? The researchers moderated each session but, the sketch mapping were led mostly by the assemblyman of each village. Places, where the activities are conducted, were described on cardboards for transcription onto ArcGIS. Data generated included village population, economic activities and engagement, and land use extent maps.

2.2.3 Data Validation

At the end of focus group discussions and mapping sessions, transect walks were conducted around the features indicated on the sketched maps. The coordinates of these features were taken using a hand-held GPS with 5 metres positional accuracy. The transect walks were mostly led by the village youth and the assemblymen. Overall, the village land use extents that were georeferenced were the last farmlands along the North, East, South and West cardinal points. It is important to emphasise that these were not supposed to create village boundary maps. This point was extensively discussed at each village, during the community entry process, and was widely accepted before the study was permitted to proceed. The sketched maps were uploaded onto ArcGIS and registered with the respective GPS coordinates for each village. The registered maps were taken back to the villages for validation. There was over 98% acceptance of the accuracies of the geo-referenced maps. The sketched maps were then digitized and were used in this study to represent the land use extents of the villages (Fig.2).

The 2010 population and economic activity data of 20 villages were also obtained from the GSS. These data were used to cross-validate the field generated population and economic activity data of the villages, using the annual intercensal rate of increase. There was over 95% agreement between these data. So it was convincing to go with the rest of the data obtained directly from the villages.

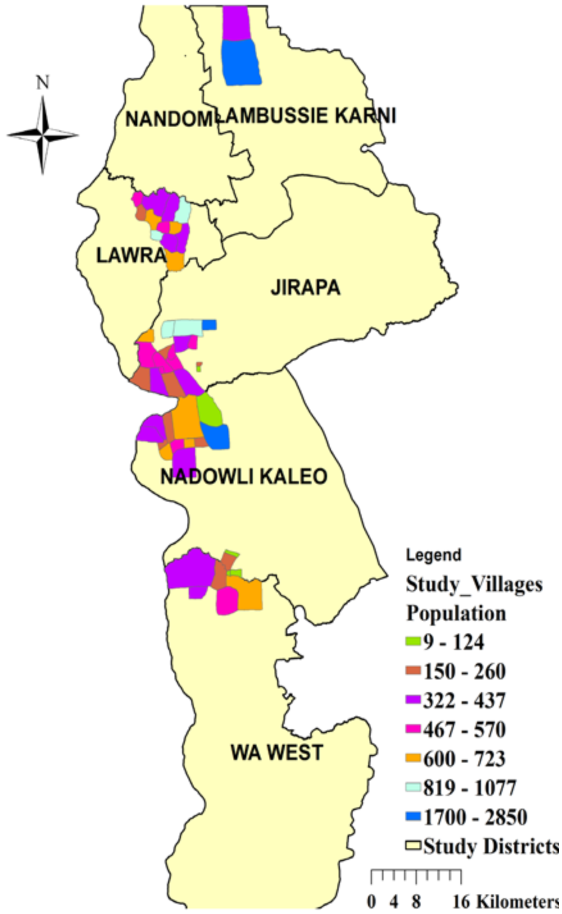

Fig. 2 Sketched sample communities

2.3 Analysis

2.3.1 Principal Component Analysis (PCA)

The major livelihood activities inventoried in each village are aggregated into principal industry categories (Table 1). The aggregation is done using the International Standard Industrial Classification (ISIC) system developed by the United Nations (UN) statistics division. The ISIC is a universal standard format. It is used for the detailed aggregation and analysis of all economic activities in a locality based on consistent, coherent concepts and definitions [31]. The ISIC Rev. 4 is used in this study to put the livelihood activities into a hierarchical, four-level-structure of mutually exclusive categories. The highest level categories are labelled as sections. The parts are coded with alphabets. The sections are then subdivided into divisions; also coded with two-digit numerals. The next lower level groups with a three-digit code. The last level is a class with a four-digit code. For instance, “Agriculture/forestry/fishing” is (section A), “Manufacturing” is (section C). Then “Mining and Quarrying" is (section B), “Wholesale and retailing” is (section G). For instance, Shea butter processing falls under section “C” “division” 10 “group” 103 “class” 1030 (Table 1).

2.3.2 The Location Quotient (LQ) model

The LQ model is used to measure the degree of specialisation of a location in the production of goods and services. It is also used to predict potential changes in a local economy when a new activity is introduced [32]. The LQ is expressed as a ratio of ratios as in the following equation:

$$\left(\frac{\mathrm{E}_{ij}/\mathrm{E}_{j}}{\mathrm{E}_{iJ}/\mathrm{E}_{J}}\right) \quad (1)$$

E = Employment; i = industry; j = village;
J = District;
LQ < 1 means production is unsatisfactory for local demand
LQ = 1 implies production is subsistence; LQ > 1 is production beyond local demand

The number of people engaged in an industry (i) in a village (j) is divided by the total number of people involved in all industries including industry (i) in the same village (j). Then, the same computation is done again with employment figures from the District wherein the village is situated. The index from the village is then divided with that of the District. The LQ is computed for all the industries identified in the communities. It explains that a community is more specialised in a particular industry than the entire District, where the LQ > 1. It also demonstrates that a village can meet its local demand for the output of an industry and can supply beyond its vicinity. An LQ = 1 means that production in that particular industry is subsistence and might not suffice for supplying its output to the market. An LQ < 1 implies that a village is in a deficit of the output of that industry and would always depend on other villages within the same District or nearby Districts, for supply.

Table 1 Principal Component Analysis and Industry categories of livelihood activities

Activities	**Principal Components/Industry**			
	AGRICFF	MINQUA	MANUF	WRETAIL
Cropping	A0111			
Gardening	A0113			
Shea butter processing			C1030	
Pito brewing			C1103	
Petty Trading				G4620/46
Food processing			C1075/79	
Wood carving			C1629	
Weaving/basketry			C1629	
Pottery & ceramics			C2393	
Sand/clay/gravel Quarrying		B0810		
Haunting	A017			
Livestock	A0141/44			
Firewood/Charcoal Burning			C1629	

AGRICFF: Agriculture/Forestry/Fishing; MINQUA: Mining and Quarrying; MANUF: Manufacturing; WRETAIL: Wholesale and retailing

2.3.3 Location Association (La)

The La model is adopted and used in this study to understand the spatial connections between different categories of livelihood. The following is the model used:

$$La = 100 - \left(\frac{\sum_{k=1}^{n} abs\langle E_{ij1,\dots,ijn} - E_{lj1,..,ljn}\rangle}{2}\right) \qquad (2)$$

i and l = industry
La ≥ 60 means strong location association La < 60 > 50 means existence of association but,
La ≤ 50 means weak association

The La is calculated by taken the sum of the absolute values of pairs of industries. The result is divided by 2 and then subtracted from 100. The expected value of La to establish the location affinity between a pair of industries is La > 60 [33]. A La between 50 and 60 is evident that there is a location association between the pair of industries. But that relationship might not be strong such that the displacement of one affects the other. Implicitly, a La < 50 shows weak relationships between any pair of industries in a location. But to explain further the binding force between a pair of industries, the Input-Output (I-O) table was used.

2.3.4 Input-Output (I—O) model

The I-O model (Leontief model), developed by Leontief [34], analyses the significance of clusters of industries in a location. The model explains the demand and supply relationships between any pair of industries at a given time. To understand this, the model uses an N*n matrix in Table 2 below to show the movement of goods and services from one industry to others. For instance, in a village setting, household constitute labour as input to the agriculture industry. Part of the output of the agriculture sector in turn is consumed domestically by the family, and part of it is supplied to the Wholesale and retail industry as an input for the market. Profits and market returns are reinvested back on farms to provide further input for the Wholesale and retail industry. Column two indicates the demand for the output x of industries 1 to n by industries 1 to N in column six. C shows the final request of the output of industries in column two and X is the total output of industries in the rows. Y is the total inputs of each industry in the columns.

Table 2: I—O flow table Adopted from Yankson [35]

		Demand Sector					
Supply Sector	**Industry**	**1**	**2**	**3**	**N**	**C**	**Total X**
	1	x_{11}	x_{12}	x_{13}	x_{1n}	$_xC_1$	X_1
	2	x_{21}	x_{22}	x_{23}	x_{2n}	$_xC_2$	X_2
	3	x_{31}	x_{32}	x_{33}	x_{3n}	$_xC_3$	X_3
	n	x_{n1}	x_{n2}	x_{n3}	x_{nn}	$_xC_n$	X_n
	v	v_1	v_2	v_3	v_n		
Total	**y**	Y_1	Y_2	Y_3	Y_n		

∑V=∑C; C-final demand for the output of each industry; X-total output of each industry

V-household sector contribution (in terms of labour); Y-total value of inputs used

2.3.5 Normalized units/life cycle thinking

The land use extent maps of the villages are overlaid with the ELs in ArcMap to identify areas of overlaps and potential displacement. The areas of overlaps are used to estimate particular village land use and associated livelihood activities that will be affected by the emerging developments. However, there is no standard model to proceed with this kind of map overlay analysis, considering the mining sector activities and potential land use conflicts. Therefore, normalised units and life cycle thinking approaches [36] are used to develop models for answering the questions in this study. The models take a Boolean approach. These are expressed as following, to determine the potential displacement of each industry in the village economy and its associated impact index:

2.3.5.1 Cultivable lands potential displacement

The types of crop farming systems practiced in the area makes every unit of land valuable for cultivation in the villages [37]. Hence, the equation below is used to calculate the cultivable lands potential displacement per village:

$$CL_{j}\_–S = [(EL_{Aj} – (EL_{Aj} \cap AFu_{Aj} \cap T_{Aj}))] \quad (3)$$

Where: –S = displacement;
CL = cultivable lands
EL = Exploration and mining Lease;
A = Area; j = village
AFu= unsuitable Agriculture and Forest land;
T = total area of village land use extents

The AFu is been excluded from the villages cultivable lands since it might not have much value for agriculture. It is also excluded from the ELs because, the analysis needs to compute the overlaps of spatial units of arable land in each village. However, the units of EL intersection AFu could be residual for the mining industry's activities. Thus, the estimated potential cultivable lands displacement is the total area of ELs in each village excluding the concurrent overlaps of ELs, AFu and villages' land use extents.

2.3.5.2 Number of households in crop farming (NhhCropF) potentially displaced

The displacement of cultivable lands has a corresponding impact on rural households engaged in crop farming as a means of livelihood. Therefore, the number of households in crop farming (NhhCropF) potentially displaced in each village due to the mining sector activities is calculated as following:

$$NhhCropF_{j}\_–S = NhhCropF2_{jt} – NhhCropF1_{jt} \quad (4)$$

But,

$$NhhCropF2_{jt} = \left[\frac{(NhhCropF1_{jt})(ACL_{jt})}{CL_{jt}}\right] \quad (5)$$

ACL= Available Cultivable Lands

The number of households in crop farming potentially displaced is determined by taking the total number of households in a village (NhhCropF1). Then subtract the NhhCropF1 from the number of households that might likely have some space to cultivate crops (NhhCropF2) in the same village, after EL was granted. But NhhCropF2 is determined by a ratio and proportion method. Multiply NhhCropF1 by available cultivable lands in a village. The product is then divided by the entire land use extents of the same village. Available cultivable lands are the suitable agriculture and forest lands in a village.

2.3.5.3 Forage potential displacement

Due to poor agricultural land use planning in the villages, there are no specially delineated grazing zones for livestock. Besides, the seasonality of forage occurrence in the Savannah regions of Ghana allows livestock free ranging. That is, animals roam even beyond villages in search of pasture during the dry season but are tethered during crop cultivation. Therefore, the entire village land, including croplands, are quantified to assess potential forage displacement and its cumulative effects on livestock keeping in villages. The following expressions are used in this analysis:

$$FDM_{j}\_–S = EL_{Aj} \times 2170 \quad (6)$$

FDM = Forage Dry Matter

The FDM per Hectare (ha) in the Northern Savannah regions of Ghana is 2170 kg [38]. Therefore, the FDM per village (FDM1) is calculated by multiplying the area of the village land use extents with 2170. Hence, FDM potential displacement per village is determined by multiplying the area of an EL in the community with 2170. The amount of FDM that might be available for livestock in a year is determined by subtracting the amount of FDM in an EL in a village from the amount of FDM in the village. This FDM is termed as FDM2.

2.3.5.4 Impacts on livestock

The displacement of FDM has negative implications for livestock keeping in each village. Therefore, the potential impacts of FDM displacement on herbivorous livestock per village is calculated using the following expression:

$$NHL_{jt\_}S = \left(\frac{Hpop \times FDM2}{Qu\_Fora} - HPop\right)_{jt} \quad (7)$$

NHL = number of herbivorous livestock

The average tropical livestock forage consumption (ATLFC) per day is 6.25 kg [39]. Therefore, the quantity of FDM (Qu_Forajt) required to feed livestock in a village is determined by multiplying the herbivorous livestock population (HLPopjt) in the village with 6.25 by 365 days in a year. Thus, the number of herbivorous livestock potentially displaced per village is determined by calculating the number of animals that would suffice FDM2. Then, the herbivorous livestock population in the community is subtracted from the result. A positive value means there would be no impact on animals. Likewise, a negative value means there would be an effect on that much of herbivorous livestock population. The number of livestock that would suffice FDM2 is calculated by multiplying the livestock population by FDM2. Then, the result is divided by the quantity of FDM required to feed herbivorous animals in a year.

2.3.5.5 Trees potential displacement

Through road, pipeline, general infrastructural constructions, as well as direct exploration and mining activities, the industry would remove valuable trees in the landscape. The number of trees potentially affected by the activities of the mining industry was estimated, considering the economic value of trees in the local economy. The techniques below were employed:

$$AvNT_{(j)\_}–S = [\sum EstNT_{yELj}] \quad (8)$$

$$EstNT_{yj} = AvTrDens_{y} \times (A)_{yj} \quad (9)$$

AvNT = Average number of trees
EstNT = estimate number of trees
y = land cover type
AvTrDens = Average tree density

The tree density per land cover type per EL has been calculated using the mean values of the estimated range of trees per hectare in each land cover. Thus, the average tree density per land cover within the EL multiplied by the area of the land cover in the EL. Therefore, the estimated number of trees potentially displaced in each village is the sum of the expected number of trees per land cover type within the overlaps of villages land use extents and ELs.

2.3.5.6 Potential impacts on Shea

The indiscriminate removal of trees would affect Shea trees in the villages. Shea been the most important economic tree in the Northern Savannah of Ghana, its potential displacement is given a particular focus in this study. The possible displacement is determined using the following expressions:

$$EstNShea_{j\_}–S = [\sum A_{ELj} \times (AvSheaDens)] \quad (10)$$

Hence,

$$AvSheaFY_{j\_}–S = EstNShea_{j\_}–S \times AvNFPT \times MFW \quad (11)$$

EstNShea = estimated number of Shea trees
AvSheaDens = Average Shea tree density;
AvSheaFY = Average Shea fruit yield
AvNFPT = Average number of fruits per tree (1247.69)
MFW = Mean fruit weight (16.25g)

The estimated Shea tree displacement is the sum of the estimated average Shea tree density within the overlaps of ELs and villages land use extents. The average Shea tree/ha is derived from dividing the estimated minimum number of Shea trees (9.4×10^{6}) with the total area of the Northern Savanna (77670 km^2) [40]. Hence, the estimated number of Shea trees per village is calculated by multiplying the index of Shea trees/ha with land use extent of each village. Likewise, the estimated number of Shea trees per EL is the ratio of average Shea density multiplied by the area of the EL.

The mean Shea fruit weight and the average number of fruits per tree are derived from the findings of Yidana [40]. These have been multiplied by the estimated number of Shea trees potentially displaced to obtain the amount of fruits potentially displaced in each village.

2.3.5.7 Potential impact on village women

The Shea industry is a dominant women activity in the Northern Savannah of Ghana. Hence, a threat to the Shea is equally a threat to the source of income to village women and children. Therefore, the potential Shea headload per women potential displacement is determined with the following techniques:

$$ShHlPW_{jt}\_{-}S\ (kg) = ShHlPW2_{jt} - ShHlPW1_{jt} \qquad (12)$$

But,

$$ShHlPW2_{jt}\ (kg) = AvSheaFY2_{jt} / FPop_{j}\_95\% \qquad (13)$$

And

$$ShHlPW1_{jt}\ (kg) = AvSheaFY1_{jt} / FPop_{j}\_95\% \qquad (14)$$

ShHlPW: Shea fruits Headload per Woman in a season; FPop: Female population

The Shea headload per woman potential displacement is determined by subtracting the initial estimated Shea headload per woman (ShHlPW1) from the likely available Shea headload per woman (ShHlPW2), after EL is granted in the village. But the likely available Shea headload per woman after EL is issued is calculated by dividing the estimated likely available Shea fruit (AvSheaFY2) after EL is granted with 95% of the total female population in a village. And the initial Shea headload per woman is also determined by dividing the estimated available Shea fruit (AvSheaFY1) before EL is granted with 95% of the female population in the village. AvSheaFY is a product of the average number of Shea fruits per tree, mean fruit weight, and the estimated number of Shea trees in a community.

3 Results and Discussions

The results in Fig. 3 demonstrate the coefficient of specialisation of all the villages in the production system. Except Banwon, Toto, Turi-Dari, Yagha-Baapari, and Musama, all the other villages have an LQ > 1 in the agriculture industry.

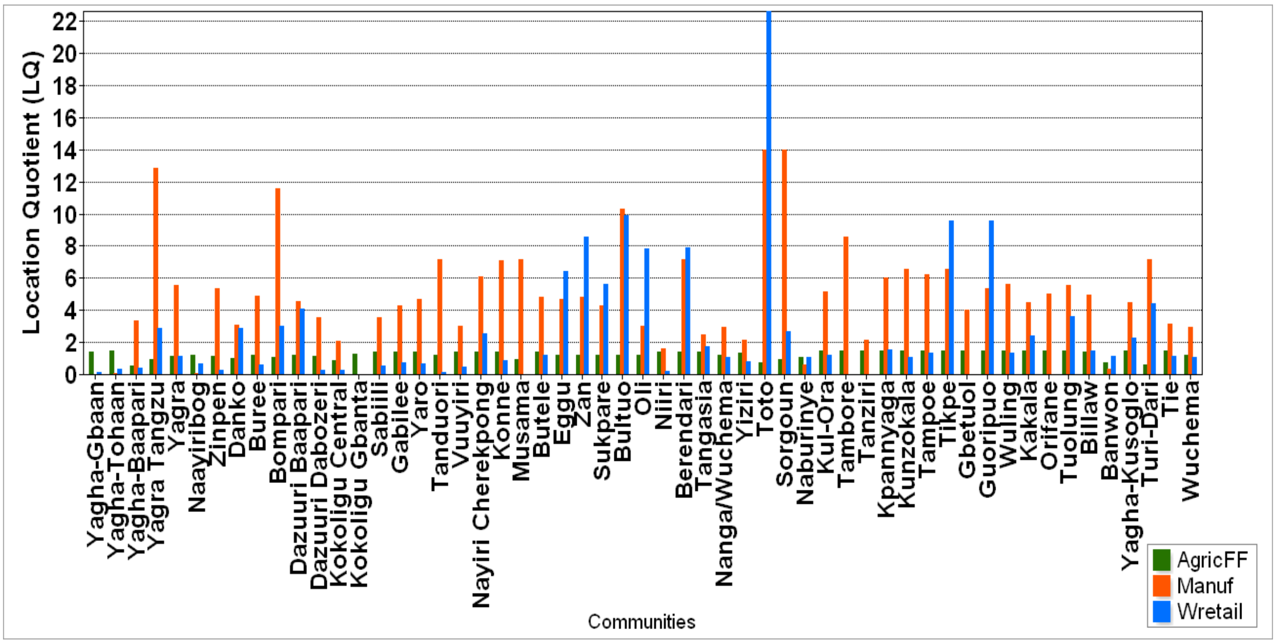

Fig. 3 Location quotient (LQ) of industry types in communities

The implication is that these communities can produce enough agricultural products to satisfy local demand. At the same time, the villages are also able to trade some of the agricultural products like food crops and livestock for income. Those villages with LQ < 1 are rather deficit in agricultural commodities and might be dependent on the more abled villages for supplies. In respect of non-agricultural livelihood activities, except Yagha-Gbaa, Yagha-Tohaan, Nayiribog, Kokoligu Gbantakuuri, Niiri, Naburnye, and Banwon, all other villages have an LQ > 1 in the manufacturing sector. Toto has the highest LQ = 23 in the wholesale and retail industry. Implicitly, a displacement of cultivable lands and accompanying forage in the villages with an LQ > 1 in agriculture would have a cumulative effect on other communities [41].

The degree of specialisation in production and the exchange of goods is a significant factor in the mechanical solidarity that exists between villages in Sub-Saharan Africa [42]. Therefore, a direct threat to anyone of the villages specialised in agriculture has implications for the survival of a chain of other villages. As a matter of food and livelihood security, communities at both producing and consuming ends might resist a common threat from the mining industry. Consequently, the total resistance to the mining industry can be predicted as the total potential displacement of both agricultural and non-agricultural livelihoods in the villages; and their neighbours in kinship and trade ties.

The results in Fig. 4 show the location association between pairs of industries in the villages. Except the mining and quarrying industry, all the industries have a La > 60 with each other. Agriculture and mining and quarrying have La < 20. Manufacturing and mining and quarrying have La = 36; wholesale and retail and mining and quarrying have La = 29. It means that most livelihood activities in these areas are spatially correlated except with the mining industry [43]. The existence of one activity stimulates the practice of a chain of others in the village. The question was whether there is location affinity between any pair of livelihood activities such that the displacement of one activity will automatically affect a chain of others.

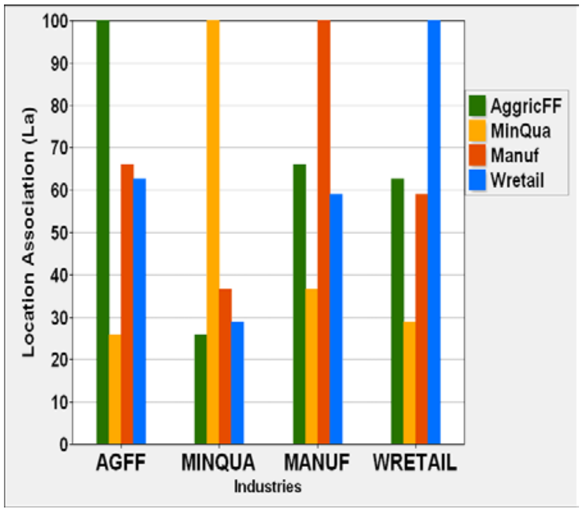

Fig. 4 Location Association (La) of industry pairing

In this respect, it is clear from the results that the displacement of the agriculture industry will affect the manufacturing and wholesale and retail industries. Thus, an introduction of the mining sector activities will have negative implications for a diversifying rural economy in the study area [41].

Importantly, Table 3 in appendix shows the material of exchange and the factors of inter-industry dependence. The agriculture sector reuses some of its outputs as principal inputs for future production. For instance, some stocks of grains of cereals are preserved and used on the farms in the following year. Also, herbivorous livestock such as cattle, are kept on farms as a means of labour and manure during ploughing and harvesting. However, some grains and livestock are sold to middlemen in the retail industry. Besides, women in village households transact wholesale and retail businesses with the family farm's products. Other households consume these in other villages and even nearby urban towns. Women also process food stuff or directly engage in catering and food vending with the farm produce of their family. They prepare local beverages from grains and cereals, which form an important component of household income. Earnings from the sale of agricultural commodities and the trading activities of families are often reinvested on the farms. Some parts of the assets are used to provide family's basic needs like payment of school fees for children, clothing and shelter. These explanations were obtained during the two fieldworks. Hence, a diversifying rural economies can be threatened with a break in the cyclical flow of inputs and outputs between industries. In the event these displacements compound livelihood constraints, village women would resist the mining industry activities.

Fig. 5 shows the overlaps between the ELs and the villages' land use extents. It can be seen from the results that some villages would have to be relocated, especially, in the Nadowli-Kaleo District, where mining licenses have been granted. The affected communities are Nanga-Wuchema, Tangasia, and Yiziri. In the Jirapa District, only Orifane will immediately be affected. However, in case of mine expansion in the current concession, Kpannyaga, Guoripuo, together with Orifane in the Jirapa District would be relocated. With the intensification of exploration, these villages' cultivable lands will be interfered with, as shown in Fig. 6. The displacement comprises a minimum of 845-1575 ha and a maximum of 2861 ha. Butele, Turi-Dari, Niiri and Berendari in the South of Nadowli-Kaleo; Eggu, Zan, and Sukpare in the Wa West District will all be affected.

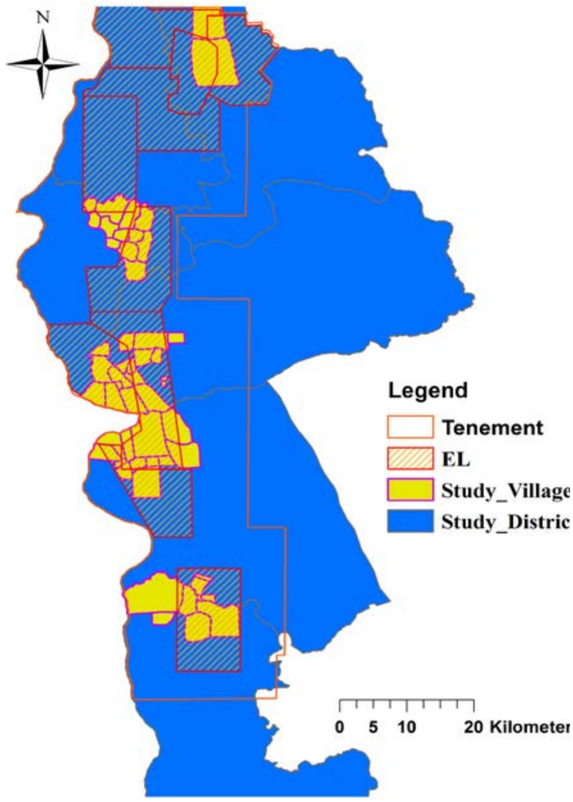

Fig. 5 Spatial interactions of villages and ELs

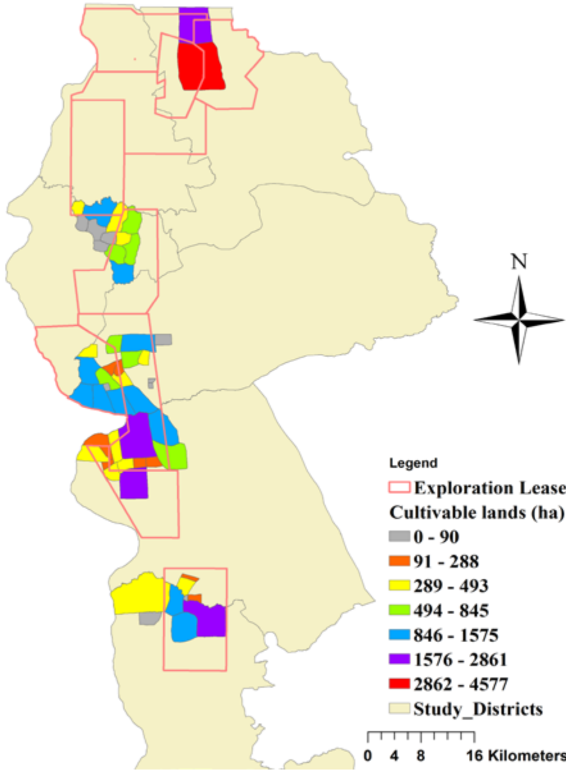

Fig. 6 Cultivable lands potential displacement

Except Tampoe, almost all the sample villages and surrounding communities in the Jirapa District will be affected by an intensification of exploration activities. Apart from Bompari, Yagra and Toto, all the sample villages in the Lawra district will be affected by exploration disturbance and future mining considerations. Billaw and Banwon in the Lambussie Karni District are no exceptions to the disturbance of the mining industry activities. Billaw has the largest land use area under the ELs. During fieldwork, it was noticed that the primary livelihood activities in the villages are land dependent. For instance, food processing, 'Pito'-brewing, and petty trading derive their inputs from cultivable lands (Table 3). Therefore, land displacement in the villages has a direct negative impact on the manufacturing, wholesale and retail industries.

Fig. 7 shows the number of trees that would potentially be displaced in each village. Billaw, in the Lambussie Karni District, will have the highest number of trees displacement, between 43781 and 69920 trees. Billaw records the highest tree potential displacement because, it is covered by the close Wooded Savanna land cover type.

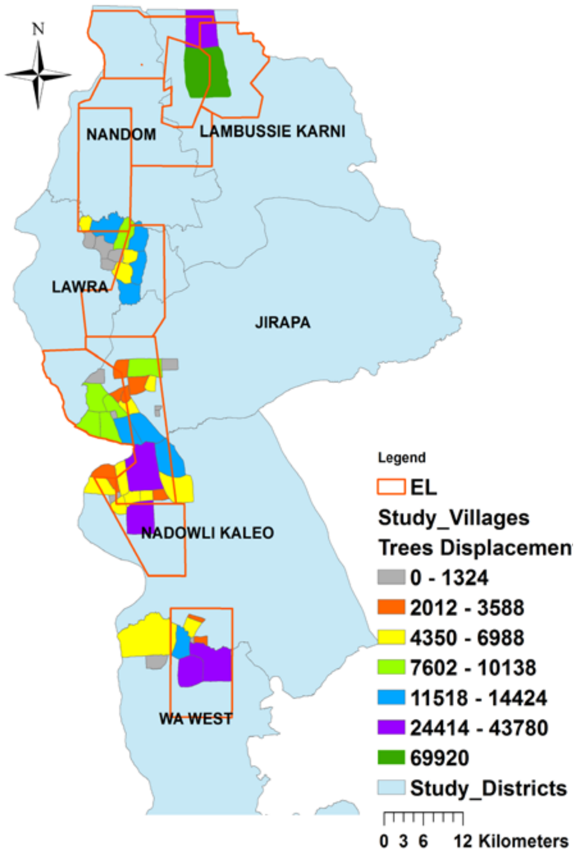

Fig. 7 Trees potential displacement

The next most potentially affected villages are Eggu, Zan, in Wa West; Konne, Nanga-Wuchema in Nadowli-Kaleo; and Banwon in Lambussie Karni districts. Villages in the Jirapa and Lawra districts will be the least affected in terms of potential tree removal. These villages are covered by the open cultivated Savanna woodland; with or without scattered trees. Tree densities in these land cover types are 6-10 trees/hectare (ha), and 0-5 trees/ha respectively. The sizes of land use extents in most of them are relatively small and, they have a comparatively small area of overlap with the ELs. Consequently, tree displacements have negative implications for the supply of inputs to manufacturing and wholesale and retail industries. Activities like wood carving, weaving, firewood and charcoal burning derive their inputs from wild trees.

Shea trees potential displacement is shown in Fig. 8. Similar to trees displacement, Billaw will experience the highest number of Shea displacement with an average of 5538 trees.

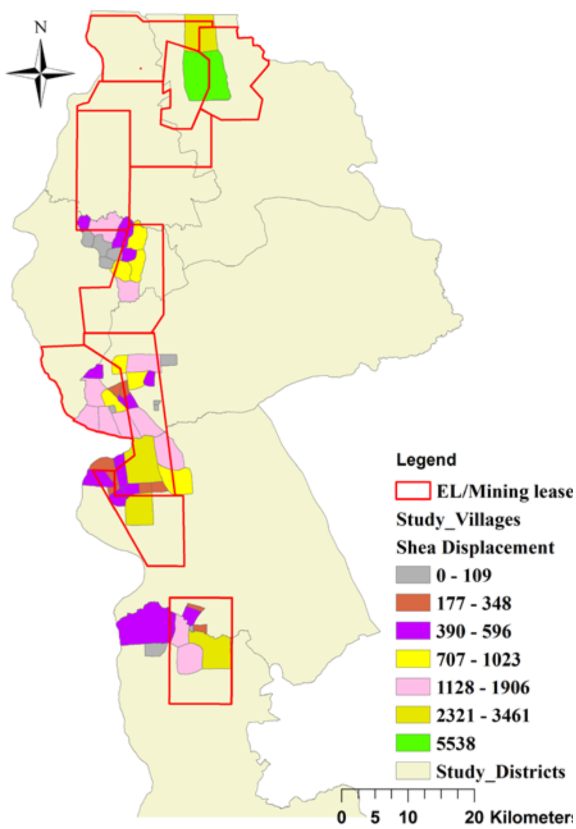

Fig. 8 Shea trees potential displacement

Nanga, Konne, Banwon and Eggu will also record the next highest Shea displacement with averages between 2321 to 3461 trees. The Shea-processing sector will be affected in most of the villages since trees displacement has an inadvertent impact on fruits loss. A minimum of 2211 kg and a maximum of 112277 kg of Shea fruits would be displaced (Fig. 9). Accordingly, Yiziri would record the highest amount of Shea headload per woman displacement. It records an average of 404 kg Shea headload per woman displacement. Nanga, Orifane, Konne, Gbetuol, Eggu and Banwon would also record between 178 kg to 265 kg of Shea headload per woman displacement (Fig. 10). The least affected villages in respect of Shea headload per woman potential displacement are Tampoe, Bompari, Toto, Yagra, Bure, Tanzire and Guoripuo. These villages either share little space with ELs or are small in size.

Thus, a displacement of Shea has an extensive negative implication on the livelihood of village women. The Northern Savannah regions have the highest female illiteracy rates in Ghana [24].

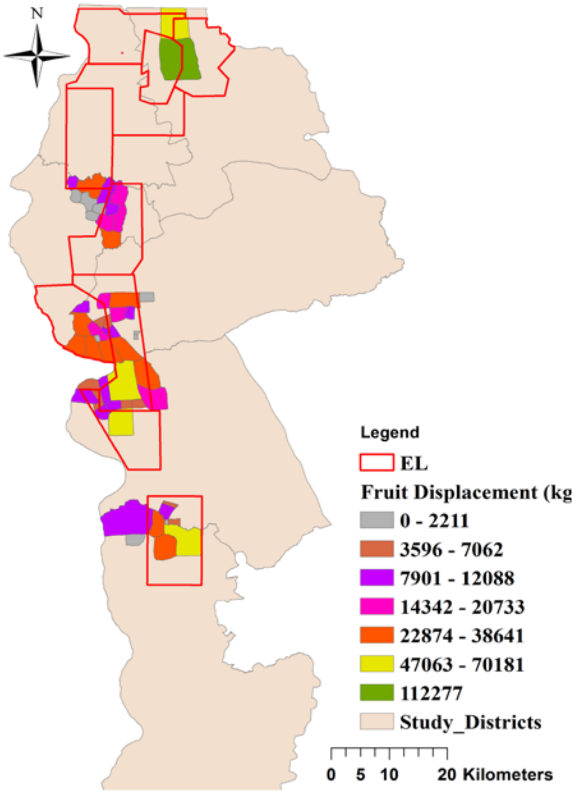

Fig. 9 Shea fruits potential displacement

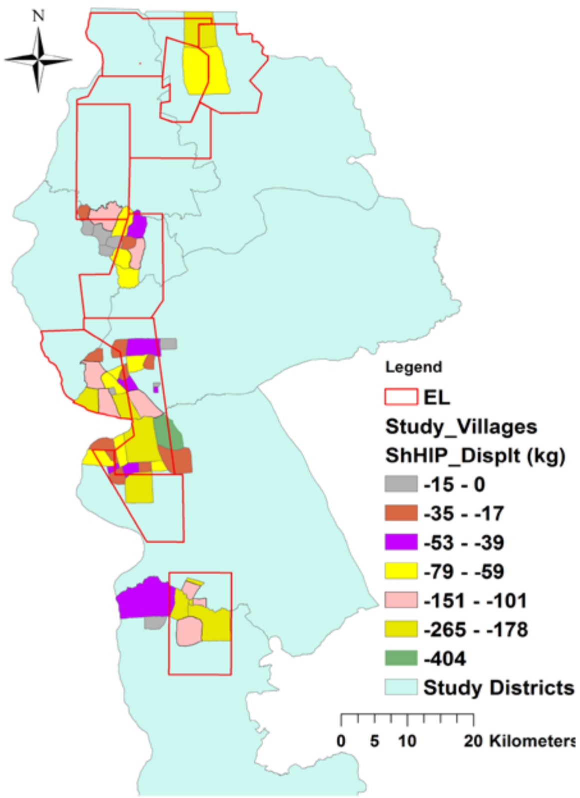

Fig. 10 Shea headload per woman potential displacement

For that matter, job opportunities for women in the villages are usually limited to on and off-farm activities, accounting for the high poverty incidences in the area. Village women in these regions depend on the Shea sector as a primary source of income with which they support their families [44]. Therefore, most development initiatives in Sub-Saharan Africa focus on the Shea sector promotion [44]. Hence, women and children would be most vulnerable to mining industry induced Shea displacement. It can, with this, be predicted that a mining sector lead displacement of Shea trees would be resisted in the area.

Lack of information and knowledge is a barrier to efficient communication and could be the primary cause of conflicts between local communities and the exploration and mining companies [4, 10]. Therefore, this study posits that there can be no efficient communication without quantifying the potential cost of the industry's activities on local communities' livelihood. Thus, the study provides necessary information about the spatial extents of the mining industry's land-use interests in the local landscape. The findings would further empower local communities and governments to understand the futures of livelihood. An understanding of communities' economic futures would stimulate efficient planning for adapting to expected economic changes. With this shared information, local communities can hold meaningful negotiations with companies and government for a better beneficiation of mineral resource returns [1, 9].

4 Conclusion

This study's primary hypothesis was that land use conflicts between local communities and the mining industry can be managed efficiently if the elements of the conflicts can be measured. Firstly, the study inventoried and characterised the livelihood activities of 55 sample villages in the study area. Agriculture, wholesale and retailing, and manufacturing all contribute to the communities' economy and lifestyle. It was found that the diversity of the rural economy makes it resilient through changing economic conditions. The study further quantified and analysed the spatial interactions between the mining industry and the livelihood activities in 53 of the 55 villages. Villages have both social and trade linkages with neighbouring communities. Therefore, indicators of socioeconomic displacement can provide efficient standards for addressing the future cumulative impacts of the mining industry on rural livelihoods.

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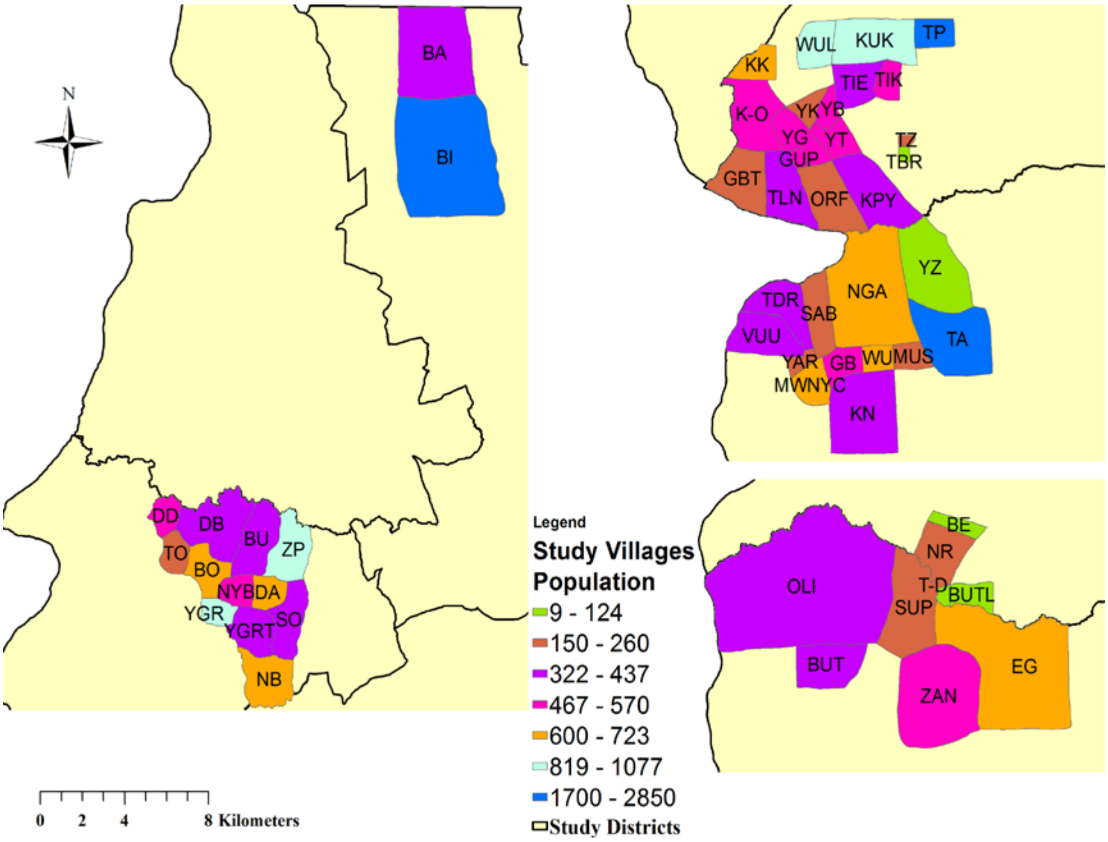
Appendix A

Table 3 The Input-Output flow table

		Demand Sector					
Supply Sector		AgricFF	MinQua	Manuf	Wretail	Household	X
	AgricFF	Seeds, animal dung/Labour	Food/land & labour	Raw grains & nuts	Raw grain, meat & Food	Food, meat & income	
	MinQua		Profits	Materials		Income, construction materials	
	Manuf	Implements	Riggings	Apparatuses	Utensils, brews, medicines, cosmetics, weaves, biofuels, construction supplies	Utensils, biofuel, drinks, medicine, cosmetics, clothing, building	
	Wretail	Fertilizers, implements, grain/seeds, pesticides, capital etc.	equipment capital	capital, tools, apparatus etc.	Capital	Income, equipment and utensils, clothing, grain and meat, beverages, cosmetics, medicines,	
	Nhh	labour	labour	labour	labour		
Total							

X: Total output Nhh: Number of households

Appendix B Labels of sample villages on Map



NAME & ABBREVIATIONS							
Dazuuri Dabozeri	DD	Gbetuol	GBT	Yagha-Tohaan	YT	Sabiili	SAB
Toto	TO	Guoripuo	GUP	Yagha-Baapari	YB	Sukpare	SUP
Bompari	BO	Kakala	KK	Yagha-Gbaan	YG	Tambore	TBR
Buree	BU	Konne	KN	Yiziri	YZ	Tampoe	TP
Yagra	YGR	Kpannyaga	KPY	Tangasia	TA	Tanduori	TDR
Naayiribog	NYB	Kul-Ora	K-O	Wuchema	WU	Tanziri	TZ
Zinpen	ZP	Kunzokala	KUK	Banwon	BA	Tie	TIE
Yagra Tangzu	YGRT	Musama	MUS	Berendari	BE	Tikpe	TIK
Naburinye	NB	Naayiri Cherekpong	MWNYC	Billaw	BI	Tuolung	TLN
Sorgoun	SO	Nanga	NGA	Bultuo	BUT	Turi-Dari	T-D
Danko	DA	Niiri	NR	Butele	BUTL	Vuuyiri	VUU
Dazuuri Baapari	DB	Oli	OLI	Eggu	EG	Wuling	WUL
Yagha-Kusoglo	YK	Orifane	ORF	Gabilee	GB	Yaro	YAR
						Zan	ZAN

CHAPTER 5 Mining and Non-Agricultural Land Use at the District Level

This Chapter is covered by the following publication:

Moomen, Abdul–Wadood, and A. Dewan. 2016. "Analysis of spatial interactions between the Shea industry and mining sector activities in the emerging north-west gold province of Ghana." Resources Policy 48:104-111. DOI: http://dx.doi.org/10.1016/j.resourpol.2016.03.001.

Analyses in this chapter focus on the entire district rather than at the village level on the basis that Shea picking has no village boundaries; people pick across villages. Moreover, the Shea tree is the most widely distributed tree species in space in the study region, about 8 out of every 10 tree stand (Lovett and Haq 2000). Besides, estimates of its economic contribution and developmental projects are usually given a cross district reference (Hatskevich, Jeníček and Antwi Darkwah 2011). In terms of negotiations, local communities are usually represented by the District Assemblies. So it adds up to understanding the economic importance of the industry at both village and district levels. The chapter also demystifies the assertion that discussions on land use conflicts between the mining industry and local communities basically focus on agriculture at the expense of other rural livelihood activities (Cernea 2003a).

Roe and Samuel (2007) in a report entitled: *Country Case Study – The challenge of mineral wealth: using resource endowments to foster sustainable development* claimed that host districts of mining sector activities in Ghana improved, economically and physically, than other districts within the same administrative region. However, reports of the Human Rights Clinic (2010) showed that there are even disparities between host local communities within the same mining district. The report further indicated that the impacts of the mining sector activities on existing livelihoods, district-wide, were more significant, taking the total district-wide contributions of particular economic sectors that have been displaced by the mining sector activities. This counter has later been confirmed by the reports of McPhail (2010). It is, therefore, important in this study to analyse all scenarios from a broader perspective, which is the host district, and narrow down to host communities. It gives a complete understanding of the differences in magnitude of the potential impacts between districts, as well as host local communities.

Moreover, not only would the displacement of Shea trees contribute to the penury of local communities but, the removal of trees, in general, would potentially contribute to the existing pace of land degradation issues in the exploration and mine operation areas. Thus, the next chapter looks at the potential socioeconomic impacts of mining-induced land degradation and displacement in the area.

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Analysis of spatial interactions between the Shea industry and mining sector activities in the emerging north-west gold province of Ghana

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ABSTRACT

The spatial interactions between valuable trees and large-scale mining sector activities provides risks and uncertainties on rural economic livelihood. This generates public clamour and resistance to mineral resource development in developing countries. Hence, this paper analyses the spatial interactions and magnitude of the impacts of large-scale mining industry activities on the Shea as an economic tree. A case study is conducted at the emerging north-west gold province of Ghana. Both primary and secondary data were obtained during two fieldworks. Whereas there is a robust Location Association (La)=70 between a Shea-led manufacturing industry and the wholesale and retail sector, a weak location association is found with mining and quarrying, and the manufacturing sectors. The associated industries are inter-dependent for inputs from the Shea tree, though the spatial analysis reveals that a minimum of 22,460 Shea trees and 806,407 kg of fruits would be displaced. The displacements would affect both manufacturing and wholesale and retail sectors, basically dominated by rural women. Albeit, the findings of the study can improve the levels of communication between local communities, mining companies and governments.

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1. Introduction

Large-scale mineral resource development is one such a high-stakes industry that has received global resistance[1] over the years. Anyhow, resource creation remains significant to the economic and physical development of both developed and developing countries. Accordingly, it requires the simultaneous occurrence of four factors: natural endowment, cultural appraisal, demand, and human capital (Roy, 2007). Although mineral resource endowment is regarded as an asset to national economies, its development is touted as a nuisance to rural livelihood since the basic needs of most rural communities is grain and meat (Downing and Garcia-Downing, 2009). These variations over the recognition of community needs, allocations and use of natural resources lead to resistances and conflicts. For case in point, rural areas harbour most countries natural resources including large land sizes, fertile soils, vegetation, and mineral deposits. However, large tracts of rural lands are often granted for mineral resource exploration and mining. These activities sometimes lead to violent conflicts, especially, in areas where large-scale mining is perceived to have negative impacts on local communities and ecosystem good.[2] These issues are increasingly common in mineral resource-rich developing countries (Hilson, 2002). Communities may block access to exploration and mining activities, or resist through public protests and the media (Boutilier et al., 2012; Resosudarmo et al., 2009).

In this regard, Wunder (2005) posits that political and social realities exacerbate the conflicts. These include: compulsory acquisition of land by governments, land privatisation; marginalisation of traditional rulers, weakened customary property rights, and rising social movements against mining (Bebbington et al., 2008; Tsuma, 2010). The conflicts may deny communities access to downstream investment opportunities, incomes, and infrastructure that would accrue from the mining sector (Bloch and Owusu, 2012). Importantly, Davis and Franks (2011) find that mining companies lose a minimum of 45% of operations time

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[1] Resistance to resource development is any activity or action or a circumstance that inhibits resource exploitation (Roy, 2007).

[2] Ecosystem goods refer to the absolute availability of land, vegetation, animal and water having socioeconomic value for humans (Nachtergaele et al., 2010).

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through conflicts with communities. Consequently, governments lose tax revenues and royalties. Nevertheless, Twerefou (2009) identifies the distribution of royalties, land use, resettlement, and small-scale mining as major areas of company-community issues. However, Hintjens (2000) finds that land use disputes are the overarching company-community conflicts. Thus, Jenkins (2004) identifies that physical and livelihood displacements[3] are central to mining-related land use conflicts. In this context, Ellis (2000) describes rural livelihood activities as economic and non-economic. Non-economic rural livelihood includes the social relationships and institutions that mediate the allocation and use of community's lands and its resources. Economic rural livelihood is diversified and comprises of On and Off-farm agriculture; and non-farm activities (Ellis, 2000).

The World Bank (2005) adds that non-farm rural livelihood is an important factor for poverty reduction in developing countries. For example, about 30–50% of household income in Sub-Saharan Africa, and up to 80–90% in Southern Africa, is derived from non-farm economic activities (Ellis, 2000). Mostly, off-farm livelihoods such as the wholesale and retail sector are derived from agricultural and tree products, and are ran by rural women (Marchetta, 2011). It is estimated that about 60–70% of rural folks in Ghana earn an economic livelihood through tree products (Obeng et al., 2011). One famous tree of high economic value is the Shea. The Shea's associated industries provide a primary source of income for rural women in Sub-Saharan Africa (Schreckenberg et al., 2006). For instance, about 95% of rural women in the Northern Savannah areas of Ghana engage in the Shea industry (Hatskevich et al., 2011). Meanwhile, in Ghana, exploration and mining activities are linked with displacements of trees with economic value (Schueler et al., 2011). This occurrence affected the trade and livelihood of women in the Tarkwa mining area of Ghana (Akabzaa, 2000). Hence, Joyce and Thomson (2000) posit that the previous experience of people influence their resistance to mining projects.

To manage the increasing mining sector land use conflicts; governments, the mining industry and scientific community have developed various tools. These include: legislative and regulatory policies, customary tools; Corporate Social Responsibility (CSR), Social License to Operate (SLO); Social Impact Assessment (SIA) and environmental analysis (Hilson, 2002, 2012; Owen and Kemp, 2013; Slack, 2012). Notwithstanding, the industry remains confronted with land use conflicts because, these mechanisms herald flawless cooperation among the various land use interest groups, which is non-existent (Catherine and Andrew, 2012). Hence, it is imperative to identify potential areas of company-community conflicts at the planning stages of exploration activities (Cernea, 2003; Joyce and Thomson, 2000).

To this end, the application of existing techniques for predicting and mitigating land use conflicts could be useful. These techniques include the LUCIS Model (Carr and Zwick, 2007), the MEDUSAT Model (Joerin et al., 2001), and Compromise programming models (Eastman et al., 1993). However, these models often entail standardisation and criteria weighting, upon which spatial suitability of competing land uses is analysed and prioritised solutions are developed. Therefore, the methods are normative and often involve mathematical algorithms that can be complex to local communities (Madani and Lund, 2011). Such complex methods accentuate existing structural inequities between local communities, the mining sector and government (Owen and Kemp, 2013).

Even so, Obara and Jenkins (2006) suggest that mining-induced displacement and land use conflicts can be addressed by examining the specific causes in isolation rather than in a holistic approach. Thus, systems engineering approach (Craynon et al., 2015), discrete choice experiments (Que et al., 2015), and aggregate complaints analysis (Moran and Brereton, 2013) have been tested for predicting potential resistance to new mining projects. However, these approaches stop short of capturing the links between local communities' land use objectives and the set of livelihood activities that do not directly depend on land. Examples include the wholesale and retail sector, which derives its input from treasured trees such as the Shea. Therefore, this study adopts non-cooperative gaming[4] technique for modelling the potential economic–livelihood displacement of mining communities (Boutilier et al., 2012). The approach provides practical framework for handling multi-criteria, multi-objective and multi-decision-maker problems (Madani and Lund, 2011). It permits the simultaneous analysis of socioeconomic and environmental issues linked with the mining sector (Craynon et al., 2015). The approach is also relevant for predicting potential land use conflicts between the mining industry and local communities, considering a non-cooperative behaviours of both (Moran and Brereton, 2013; Que et al., 2015).

Thus, the study maps and analyses the spatial interactions between Shea trees and the mining industry activities (exploration/mining concessions); allowing for spatial interpretation of potential conflict areas. Hereafter, it identifies the location affinity between the Shea industry (herein categorized as manufacturing), mining and quarrying, and the wholesale and retail industries. That is where a displacement of the Shea industry may have rippling effects on other parts of the local economy (Moran and Brereton, 2013). The study further illustrates the potential impacts of Shea displacement on already vulnerable rural women in the event of mining. The scope of this study is novel in a burgeoning literature concerned with corporate community land use conflicts in developing countries. Not many other studies have considered a displacement of the Shea industry, by large-scale mining sector activities, as a major source of corporate community conflicts as ours does.

2. Materials and methods

2.1. The study area

Ghana leads in gold production in West Africa and second in Africa (Mines, 2013). It also hosts substantial deposits of aluminium, manganese ore, bauxite and diamond (Coakley, 1996). Politically, Ghana has been divided into 10 administrative regions. The Northern, Upper East and Upper West Regions are the three in the north.

Historically, Ghana's mineral concessions were concentrated in the southern regions of the country. But, with recent discoveries of world-class gold deposits, plans are far advanced to start large-scale extraction of gold in the Upper West Region (Azumah Resource Limited, 2013). This development warrants this paper to explore a case study in the area (Fig.1). Upper West, with Wa as its regional capital, is the second poorest region in the country (GSS, 2007). Nevertheless, the economic contribution of the Shea industry to the livelihood of households in this region cannot be underestimated (Yidana, 2004). Thus, Shea trees constitute about

[3] Physical displacement involves the overall relocation of settlements and livelihood from their current occupancy to a different location (Cernea, 2000). It also involves reductions or loss of quality and quantity of environmental resources such as ecosystem goods. Economic or livelihood displacement entails the imposed or induced loss of assets, and income on the affected local communities ibid., Downing (2002).

[4] The Game theory is a study of conflicting multiple objectives where each player's decisions and actions potentially affect the interests of the other players (Madani and Lund, 2011).

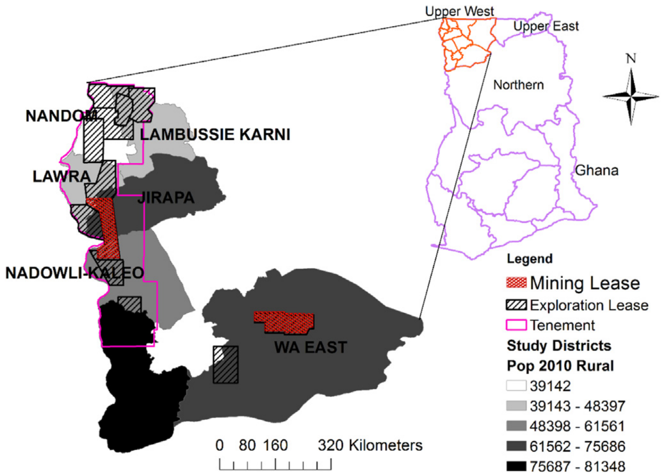

Fig. 1. Location of study area.

80% of woody biomass in the area (Lovett and Haq, 2000). Therefore, the introduction of mining sector activities in the region is predicted to generate land use conflicts, since the industry largely displaces tree cover in the landscape.

Ghana operates the District Assembly system of local governance. Currently, the Upper West Region has eleven District Assemblies, and this study covers seven out of the eleven. Two districts have mining leases granted along with ongoing exploration leases. These are Nadowli-Kaleo and Wa East Districts (Fig. 1). The rest have exploration leases; namely Wa West, Jirapa, Lawra, Nandom, and Lambussie-Karni districts.

2.2. Data collection

Two field works, for data collection, were conducted between November 2013 and February 2014; and between November 2014 and February 2015. The study area is defined into clusters of communities hosting drill holes, active mine concessions and exploration leases in each district. These communities are; Nanga, Tangasia, and Yiziiri in the Nadowli-Kaleo district. The others are Eremon in Lawra district; Kokoligu in Nandom district; Yagha in Jirapa district; Eggu in Wa West district; and Billaw in Lambussie-Karni district. Polygon map, data on population and economic activities by districts were acquired from the Ghana Statistical Service (GSS). Exploration leases and concession maps were downloaded and digitised from report 43-101 of Azumah Resources[5] Pty Ltd. These were used to assess the spatial extents and interactions between mining and communities' interests. District profiles[6] were also obtained to appraise the social, economic and environmental conditions of the area. Three separate focus group discussions (FGDs)[7] were held in each community. During these sessions, the localities livelihood activities, development objectives, local knowledge, experiences and perceptions of the incipient mining industry activities were inventoried. Community groups identified were: women associations, youth associations, area councils and unit committees. The rest are community experts including experienced farmers, hunters, and earth priests. Due to resource constraints, no village in the Wa East district was sampled.

The focus group discussions had a minimum of eight and a maximum of 10 participants in all the villages, giving a total of eighty (80) participants. The discussions were semi-structured interviews, moderated by the researcher. Questions presented to the groups for discussions include: “Which livelihood opportunities exist in the community in respect of: (a) trees and plant materials harvested for food, clothing, medicines, shelter, tools, rent; and (b) rocks, minerals, and soils collected for making tools, ceremonies, shelter, rent, or farms”? “What are the prospects of possible peaceful co-existence between existing livelihood activities and the emerging mining sector activities”? Notes were taken from informal discussions with a total of 25 local authorities from the District Assemblies and the Savannah Accelerated Development Authority (SADA). The purpose of the discussions was to obtain a local governance sector perceptions of the emerging mining sector activities and local communities' livelihood. However, the mining and exploration companies[8] with current tenements and concessions in the area were inaccessible. Non-Governmental Organisations (NGOs)[9] were not also accessed at the time of fieldwork.

2.3. Data analysis

2.3.1. Shea trees and ELs spatial interactions

To assess the spatial extents and interactions between the mining sector activities on one hand and the distribution of Shea trees and non-agricultural economic livelihood activities on the other hand, the following equations were developed and used in this study:

$$\mathrm{EstNShea1}_{jt} = \mathrm{AvSheaDens} \times \mathrm{Area}(A)_j \tag{1}$$

$$\mathrm{EstNShea2}_{jt} = (8) - \left[\sum A_{ELj} \times (\mathrm{AvSheaDens}) \right] \tag{2}$$

$$\mathrm{EstNShea}_{j\_}\text{–}S = \left[\sum A_{ELj} \times (\mathrm{AvSheaDens}) \right] \tag{3}$$

AvNShea: Average Number of Shea trees in the Guinea Savanna area of Ghana $= 9.4 \times 10^6$; Area of Northern Savannah $= 77{,}670\ \mathrm{km}^2$; AvSheaDens: Average Shea trees Density.

AvSheaDens/km$^2 = 121$–1.21/ha; derived from Oppong-Anane (2006) and Yidana (2004).

EstNShea: Estimated Number of Shea trees (1) before exploration lease (EL) and (2) after exploration lease (EL) was granted.

To estimate the Shea tree density/km^2, the average number of Shea trees (9.4×10^6) in the Northern Savannah is divided by its total area ($77{,}670\ \mathrm{km}^2$). However, densities in closed Savannah woodlands may be more than estimated. This disparity was observed during fieldwork. The estimated number of Shea trees (EstNShea1jt) in a district before EL was granted is the product of the average Shea tree density per hectare and the geometric area of the district. The estimated number of Shea trees covered within an EL in a district is the product of the average Shea tree density per hectare and the area of an EL in the district. Therefore, the number of Shea potentially available in any district in a season is estimated by multiplying the sum of Shea covered in each EL in the district by the average Shea density per hectare. The result is then subtracted from the estimated Shea density in a district before EL was granted. Hence, potential Shea displacement is

[5] Azumah resources is an exploration company currently holding mining licences in the study area.

[6] These are documents containing both biophysical and socioeconomic information of the districts.

[7] Focus group discussions are an efficient tool for taking inventory of the characteristics, opportunities and risks of livelihood activities in a locality (Chambers, 1994).

[8] Formal letters written to the company were followed up with personal visits and emails. The company finally replied to one of the emails, citing shortage of personnel and time to participate in the FGDs. The company, however, referred the researcher to their website for any information needed.

[9] As at the time of fieldworks, the DAs, especially Nadowli-Kaleo, indicated that all NGOs interested in the study were on break, and some had vacated site upon end of programmes.

determined by subtracting the Shea density in a district, before EL was allowed, from the density of Shea available, after EL was granted.

2.3.1.1. Shea fruit yield potential displacement. The potential Shea fruit displacement due to Shea trees displacement was also assessed using the following equations:

$$\text{WAvNFPT} = \text{MFW} \times \text{AvNFPT} \tag{4}$$

$$\text{AvSheaFY1}_j = \text{WAvFPT}_j \times \text{EstNShea1}_j \tag{5}$$

$$\text{AvSheaFY2}_j = \text{WAvNFPT}_j \times \text{EstNShea2}_{jt} \tag{6}$$

$$\text{AvSheaFY}_{j}\_{-S} = \text{EstNShea}_{j}\_{-S} \times \text{AvNFPT} \times \text{MFW} \tag{7}$$

- MFW = 16.25 g and AvNFPT = 1247.69 adopted from Yidana (2004).
- WAvNFPT: Weight of Average Number of Fruits Per Tree; MFW: Mean Fruit Weight.
- AvNFPT: Average Number of Fruits Per Tree; AvSheaFY: Average Shea Fruit Yield.

To calculate the Weight of Average Number of Fruits per Tree, the Mean Fruit Weight in kilograms (kg) is multiplied by the Average Number of Fruits per Tree. To estimate an Average Shea Fruit Yield in a district before EL was granted, the weight of an average number of fruits per tree is multiplied by EstNShea1 in the district. The potential Shea fruit displacement is measured by taking the product of Shea trees possible displacement in a district and the weight of the average number of fruits per tree in that same district.

2.3.1.2. Potential effect on women. The potential displacement of women's major source of livelihood and income through Shea processing sub-industry in the area was analysed using the eqautions below:

$$\text{ShHlPW}_{jT}\_{-S} = \text{ShHlPW2}_{jT} - \text{ShHlPW1}_{jT} \tag{8}$$

$$\text{But;ShHlPW2}_{jT}\,(\text{kg}) = (13)/\text{EstNW}_j\_\text{PickShea} \tag{9}$$

$$\text{ShHlPW1}_{jT}\,(\text{kg}) = (12)/\text{EstNW}_j\_\text{PickShea} \tag{10}$$

- EstNW_{jT} _PickShea = FPop_{jT} – Error Margin (5%); FPop: Female Population
- ShHlPW: Shea fruits Headload per woman in a season
- EstNW_PickShea: Estimated number of women who pick Shea fruits

Trees displacement may not result in a decline in the number of pickers but, the quantities often picked may reduce. Thus, Shea Headload per Woman potential displacement (ShHlPW_-S) in each district in a season T is estimated by deducting the probable Shea headload per woman (ShHlPW1jT) before EL was granted in a district, from available Shea headload per woman after EL was granted (ShHlPW2jT). But, to measure Shea headload per woman before EL was granted, divide average Shea fruit yield (AvSheaFY1) in a season with 95% of the female population in each district. Likewise, to measure Shea headload per woman after EL was granted, divide the average Shea fruit yield per tree after EL was issued, with 95% of female population in a district.

2.3.2. Location association (La) model

The location Association (La) method was also used to express the spatial distribution and affinity between pairs of industries. Thus, a displacement of one sector directly affects the other sectors. In this technique, we calculate the percentage value of each industry pair, say A and B, in each sub-location within the study area. Then B is subtracted from A (A–B) for each sub-location, and the absolute values are summed, divided by 2 and the result is subtracted from 100. The technique is expressed in the formula below:

$$\text{La} = \left[100 - \left(\left(\sum \text{abs}\langle E_{ij1,\,ij2,\,ij3\,\ldots ijn} - E_{lj1,\,lj2,\,lj3\ldots ljn}\rangle\right)/2\right)\right] \tag{11}$$

where i and l = industry types; La ≥ 60 means high degree of association; La < 60 > 50 means evidence of association; La ≤ 50 means weak association; j = district.

The value of the La varies from 0–100. The higher the La of any pair of industries, the stronger the spatial association between that pair in the area. Usually, La > 60 is required to establish that there is strong relations between a couple of industries (Feng and Ji, 2011). Conversely, La < 50 indicates a weak spatial attraction between any pair.

2.3.3. Input–output model (I–O)

The 2008 revised edition of the International Standard Industry Classification system (ISIC, Rev.4) was used to aggregate the livelihood activities of local communities into industry groups. The ISIC is a widely used tool at international and national levels for collecting and reporting statistics of social and economic activities at local levels. The input–output (Leontief) model was then used to analyse the interdependence between industries for inputs. It is a matrix that explains the exchange and flow of goods between industries within a district or between industries in different districts. The input–output model is expressed in an N*n matrix in Table 1 below. The column values from $x11$ to $xn1$ indicate demand for the output x of industries 1 to n by industries 1 to N as their input in the row. C is the final demand for the output of each industry in the column; X is the total output of each industry in the columns and; Y is the total amount of X used as input by each industry in the rows.

- x-flow of output from one industry to another as an input within the same location.
- C-final demand for the output of each industry.
- X-total output of each industry Y-total value of inputs used.
- V-household sector contribution (in terms of labour).
- The table only explains how modifications upon one activity can affect other activities in the same district. But the cross-district I–O is expressed as following:

Table 1
Input/output flow table adopted from Yankson (2011).

		Demand sector					
Supply sector	Industry	1	2	3	N	C	Total X
	1	x_{11}	x_{12}	x_{13}	x_{1n}	$_xC_1$	X_1
	2	x_{21}	x_{22}	x_{23}	x_{2n}	$_xC_2$	X_2
	3	x_{31}	x_{32}	x_{33}	x_{3n}	$_xC_3$	X_3
	n	x_{n1}	x_{n2}	x_{n3}	x_{nn}	$_xC_n$	X_n
	v	v_1	v_2	v_3	v_n		
Total	y	Y_1	Y_2	Y_3	Y_n		

$\sum V = \sum C$

$$ {}_{k}X_{i} - \sum_{l=1}^{l=n}\sum_{j=1}^{j=m} {}_{\mathrm{kl}}x_{\mathrm{ijk}}Y_{i} \qquad (12) $$

$i = 1, 2, 3 \ldots .. m$; $k = 1, 2, 3 \ldots n$

i=supplying industry in k=supplying location, and j=receiving industry in l=receiving location.

Eq. (12) above also explains how changes in the industrial activities of one district (A) can affect the activities of other districts (B), where B is linked to A for input (Isard, 1951; Leontief, 1987). However, this model is unable to stand alone to give a holistic visual impression of the magnitude and trajectory of anticipated impacts on the local economy (Stimson et al., 2006). Hence, it supplements the models used above.

3. Results

3.1. Shea trees/fruits displacement

Fig. 2 shows the estimated number of Shea trees potentially displaced in each district and the accompanying Shea fruits and nuts displacement. The Nandom and Wa East districts would experience the highest number of Shea trees (39,774) and fruits (806,407 kg) displacement. Wa West has the lowest number of trees potential displacement (22,460). Again, Wa West and Lawra districts have the lowest fruits potential displacement (455,368 kg).

3.2. Shea headload per woman displacement

The results in Fig. 3 show that the potential Shea headload displacement per woman per district resonates with the potential fruits and trees displacement. A maximum of 36 kg in the Nandom district and a minimum of 11 kg of Shea fruits in the Wa West district would be displaced from Shea picking women. This result was expected to be negative in all districts since trees and fruits displacement is inevitable in mining concessions.

3.3. Location association between local industries

The results in Fig. 4 show that the Manuf has La ≥ 70 with the Wretail industry. However, the manufacturing (Manuf), and wholesale and retail (Wretail) both have La < 60 with the mining and quarrying industry (MinQua). The La between the Manuf and any industry explains the potential rippling impacts that a displacement of Shea trees can have on others.

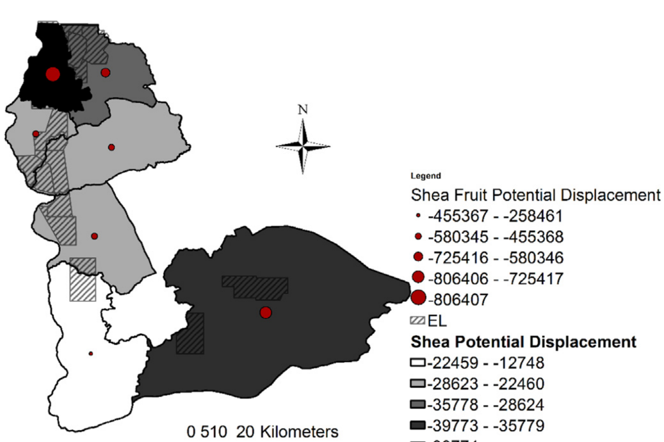

Fig. 2. Shea trees and fruits potential displacement.

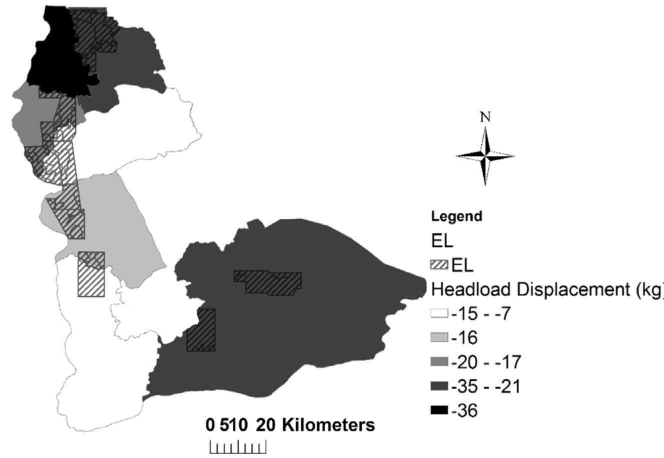

Fig. 3. Shea headload per woman potential displacement.

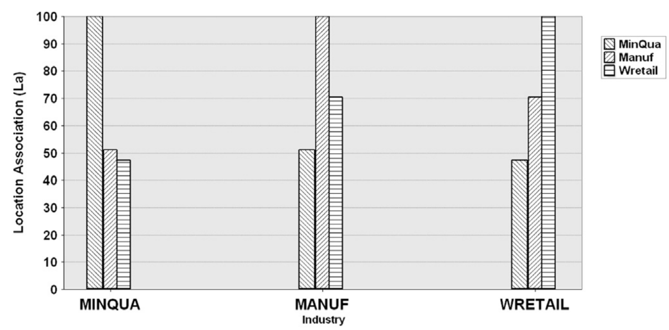

Fig. 4. Location association (La) by districts.

3.4. Inter-dependence of industries for input–output

The ISIC system categorises Shea processing, carving, charcoal burning, and weaving under manufacturing, as practiced in the local communities. The Shea processing sub-industry produces soap, butter, cooking oil, and herbal medicines for household use. Sales of these products are also used to remit household basic needs such as feeding and health cover. Local craftsmen use the stems, branches, roots and leaves of trees and plants to produce handles of local equipment such as hoes and rakes (Table 2). The wholesale and retail vendors mostly patronise these handles and sell in the markets.

4. Discussions

During fieldworks, it was found that the local communities have resisted the introduction of the mining industry activities in the area. At the study's community entry phase and focus group discussions, the local people indicated their unwillingness to grant individual interviews. Reasons were that the exploration/mining companies use similar methods to engage with people who do not share the general objectives, opinion and resentments of the populace. Subsequently, they (companies) declare the communities' acceptance of their activities. Thus, members of the communities, expressed bitter sentiments against the appearance of the exploration/mining activities in the area. It was reported that communities' farmlands and most significant economic trees, which is the Shea, are been destroyed by the company without adequate compensations or prior consent. In the Nadowli-Kaleo district, village women expressed their unhappiness since company security

Table 2
The Input-Output flow table.

Supply sector	MinQua	MinQua	Manuf	Wretail	Household	X
			Materials		Construction materials	
	Manuf	Tools	Capital tools and handles	Tools, handles, beverages, medicines, cosmetics, textiles and fashion, bio-fuels, and construction materials	Beds, charcoal, firewood, beverages, medicine, cosmetics, and utensils	
	Wretail	Tools and equipment (shovels, rakes, pick-axe, hoes, and pans)	Premium, tools, materials and equipment (machetes, shovels, cutlass, sacks, etc.)	capital	Furniture equipment and utensils, clothing, food and grain, beverages, cosmetics, and medicines	
Household	Labour	Labour	Labour			
Total						

X: total output; Nhh: number of households.

would not allow them access to Shea trees within the concessions. Thus, the minerals and mining act 703, section 72 of the 2006 minerals and mining act of Ghana grants companies with mining leases the prerogative to repudiate communities' surface rights. This affects communities' access to herbal medicine; families' capability to provide school fees, feeding and other basic needs.

Therefore, the communities have sent out signals of violent confrontations with the exploration and mining companies, should actions not be expedited to address, adequately, their concerns. Opinion leaders and community youth have petitioned the District Assemblies, Minerals Commission, the sector Ministry, Regional House of Chiefs, and the Environmental Protection Agency against the mining sector activities in the area. However, as at the time of last fieldwork, the communities indicated their frustrations with non-response to the petitions. Although the assemblies have acknowledged receipt of the communities' calls, they are unable to mediate because, the exploration/mining companies have not established links with them. As a result, there is an emerging trend of conflict between: the youth and communities elders; communities and companies; assemblies and companies; and between local and central governments. Whereas the young people in the communities accuse the chiefs and elders for selling their land and trees of economic value to the companies, the latter also point accusing fingers at the government. This has broken the social bondage that exists between youth and elders in the area. Besides, the minerals and mining law of the country requires the appraisals and inputs of District Assemblies and local communities to proposed projects in their economic space: to accept or reject the projects proposals with convincing evidence. But it is discernible from discussions with the local authorities that, these due processes were not adhered before exploration/mining companies' appearance in the area.

Considering the biological, cultural and economic importance of trees to local communities in the study area, the displacement of Shea trees is a critical source of conflicts between companies and communities. Biologically, Shea trees are used to manufacture local medicines and herbs. Herbal medicine is integral to the well-being of rural people in these areas. Culturally, trees are preserved to form sacred groves whereby traditional worshippers and local communities derive spiritual sustenance. Moreover, it is found that sacred groves have strong location association (La) with rural economies in Ghana (Blench and Dendo, 2004). But the results in Fig. 2 show that the mining industry's activities would displace a significant amount of trees. Shea trees would constitute about 80% of this volume (Lovett and Haq, 2000). Notwithstanding, during fieldwork it was observed that Nandom district has less Shea tree densities as compared to the rest of the area. But regarding Shea tree displacement, Nandom district may have the highest due to the size and number of its exploration leases.

The results further show that the mining and quarrying industry has weak location attraction with both manufacturing and wholesale and retail sectors (Fig. 4). Therefore, the possibilities of forward and backward linkages is a non-sequitur. Nonetheless, it is evident that economic livelihoods in the local communities are an inter-dependent web upon which families have sustained their economic resilience (Table 2). Importantly, the results support the findings of earlier studies that, rural livelihoods in the Northern Savannah regions of Ghana are diversifying from agricultural to non-agricultural (Marchetta, 2011). Whereas employment in agriculture decreased from 74.5% to 57.1% between 1997 and 2003, the manufacturing, and wholesale and retail areas are increasing in employment (GSS, 2007). Hence, displacement of a primary input of the manufacturing sector, in the Jirapa and Nadowli-Kaleo districts, would indirectly affect inputs to the wholesale and retail industry. These effects would echo a corresponding wider impacts of mining sector activities on income levels of the people. For these reasons, mining land use potential impact assessments should recognise the composite economic systems of local communities as a crucial source of conflicts.

Rural households are sustained, throughout the Off-farm seasons, with the coordinating support activities of women in the local manufacturing industry (Marchetta, 2011). The Shea subsector contributes more than 12% of rural household income during this period (Pouliot, 2012). As a result, most poverty reduction programmes in Sub-Saharan Africa prioritise an improvement of the Shea industry (Hatskevich et al., 2011; Schreckenberg et al., 2006). Shea picking, unlike farmland ownership, is open access. Any person can pick in the wild, depending on how far she can go for gathering. Thus, the number of women possibly displaced is not an ideal measure in this context but, it was laudable to measure the potential displacement based on the average headload a woman can gather in a season (Fig. 3). Whereas households can pick up to 5760 kg of Shea nuts in a season, individuals can pick up to 80 kg of the kernel (Carette et al., 2009; Hatskevich et al., 2011). Meanwhile, it is found that women and children are most vulnerable to impacts of mining-induced displacement (Owen and Kemp, 2015). Only a few women gain employment in the industry or benefit from its activities. Therefore, a mining sector-led displacement of Shea trees and fruits would have a telling effect on rural women.

The current circumstances reflect, presumably, a lack of steady public sector support for addressing communities concerns before mine operation. Hilson and Nyame (2006) lament that the outrage public debate against mining on valuable tree cover spaces, which grant livelihood security to Ghanaian rural communities, presages a paucity of solid baseline socioeconomic and environmental impact assessments in the Ghanaian mining sector. Whiles the government of Ghana seeks to permit the removal of economic trees for mining, there is an enormous civic backing for communities' resistance. In this regard, Taabazuing et al. (2012) note that the minerals and mining policies in Ghana do not reflect strategies for synergies between rural livelihood and large-scale mining sector activities. This results in the upsurge of illegal Artisanal Small-scale mining (ASM) sector in many parts of the country (Hilson and Yakovleva, 2007), accounting for over 50% of redundant rural female populations (Yakovleva, 2007). The preceding, therefore, suggest the absence or weakness of a systematic mechanism to mitigate looming violence between relevant mining sector stakeholder groups in Ghana.

5. Conclusions

Analysis of the spatial interactions between Shea trees and large-scale mining sector activities offers baseline evidence of the risks and uncertainties of rural economic livelihood. This has already met public clamour and resistance in an emerging gold province of Ghana. Local communities' livelihood activities were aggregated into three broad industry categories: agriculture; manufacturing and wholesale and retail industries. The analysis measured the potential impacts of exploration/mining activities on local manufacturing; and wholesale and retail sectors due to a displacement of Shea trees. The Shea tree is a primary input to the local manufacturing sector. The manufacturing sector is found to have a strong location association (La) with the wholesale and retail sector. Both industries are major areas of livelihood for rural women. Hence, it is found that the mining industry would displace the main source of income to village women in the area.

Albeit, the findings of this study provide common knowledge base otherwise inaccessible to local communities (Carson, 2005). This knowledge can be shared to improve the communication gaps between local communities, governments and companies (Barclay et al., 2012). It could also enhance an efficient development of a mining sector that may bring mutual beneficiation between the local communities, local and central governments and the mining industry, without compromising the existing livelihood activities of host communities (Mining Vision Africa, 2009). Also, the findings would contribute to the efforts of District Assemblies, government and other sectors in respect of generating relevant data for an efficient management of the mining sector activities (Amanor et al., 2005; Carson, 2005). This challenge is a critical area that has received little attention from academic research, thereby, inhibiting improvements on a peaceful co-existence between local communities and the mining industry.

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CHAPTER 6 Potential Mining-Induced Land Degradation and Displacement

This Chapter is covered by the following publication:

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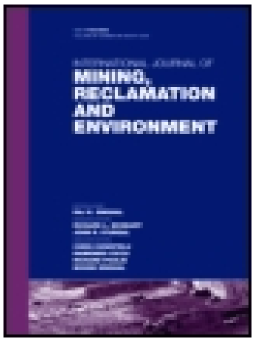
In this chapter, the potential socioeconomic effects of exploration and mining-induced land degradation have been analysed at a district-wide perspective. A critical contribution of the mining sector to land degradation is the depletion of tree cover and grasslands that leads to soil acidification, erosion, effects of flooding, soil and water pollution (Mbaya 2013). Through these defects, both agricultural and non-agricultural livelihood activities of local communities would be displaced, leading to conflicts.

Previous chapters illustrate that people living in rural areas largely depend on agriculture. Evidence also abound that mining-induced pollution of farmlands resulted in reductions in soil fertility and a consequent depression of farm yields (Aragón and Rud 2015; Mbaya 2013). Apart from the economic benefits of Shea, trees are also used for the production of charcoal and local herbs in sub-Saharan Africa (Duku, Gu and Hagan 2011; Blench and Dendo 2004). Thus, the capacity of land and its resources to support the mining sector activities and at the same time provide rural community resources for livelihood must be understood in a district-wide perspective. This understanding would provide a first-line indication of possible pressures on local livelihoods, which would allow harmonized interventions to be made before, during and after mining.

Land degradation and its effects travel beyond their origin. However, due to limited availability of data in most resource-rich developing countries, the potential extents of land degradation caused by mining, and its potential impacts on populations are unknown (World Bank 2006; EPA 2003; Twerefou 2009). Although local causes of land degradation have been identified in many case studies, these have not been catalogued systematically at the district level. Therefore, the analyses presented in this chapter quantify answers to some of these questions. In particular, where land degradation would take place in exploration and mining concessions, the impact it would have on the livelihood of the affected people is also investigated.

In this 21st century, human populations are steadily increasing; previously rural communities are becoming urbanised, whilst people are getting poorer in Africa (African Union 2014). The effects of land degradation is much more felt in areas with high population densities and high poverty levels (Nachtergaele et al. 2010). Consequently, incidents of land degradation and water stress are also increasing in these areas (Nkonya et al. 2011). Meanwhile, the mineral resource sector, which is largely associated with land degradation, especially open cast surface mining, is predicted to expand its operations in these areas. However, the spatial extents of the environmental implications of a looming mineral resource sector at the local levels are unknown (Africa Mining Vision 2009). Hence, models for calculating land degradation indices and associated impacts have been adopted from Nachtergaele et al. (2010) on the Global Land Degradation Information System (GLADIS). By far, GLADIS presents the most comprehensive approaches to estimating land degradation and its potential effects on inhabitants. Thus, the impacts of land degradation indices are calculated using figures of poverty indicators against population densities in the area. Areas with no population means no impact of land degradation; areas with <25 population show low degradation risk; and those with >75 are high risk areas (Nachtergaele et al. 2010).

It is noted that large-scale mining activities are significant drivers of land degradation and desertification (Kitula 2006; Gao and Liu 2010). Land degradation leads to soil erosion and stream bed sedimentation, which reduces the volume of surface water bodies (World World Bank 2006; EPA 2003; Nkonya et al. 2011). However, incorporating the potential effects of mining-induced land degradation on water availability, for agricultural and domestic uses in exploration and mining concessions, is generally lacking in mineral resource rich developing countries (Toledano and Roorda 2014). Thus, the next chapter analyses the spatial interactions between the mining sector activities and, water quality and quantity for any use in the study area.



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Assessing the spatial relationships between mining and land degradation: evidence from Ghana

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ABSTRACT

The relationships between mining and land degradation, their potential socioeconomic impacts and extents were quantified and analysed in this study. A case study was conducted in the Upper West, which is an emerging mining region in Ghana. Land cover, socio-economic and monthly rainfall data were used in GIS. Mining-induced land degradation indices range from 0.02 to 0.80. The Fournier co-efficient model was used to obtain erosivity indices between 42 and 84 mm, bringing mining concessions into severe erosivity zones. The results of this study will facilitate a concerted effort by governments and companies to prioritise sustainable mining and rural development.

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Mining; land degradation; erosion; displacement; mapping; Savanna

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Introduction

In its quest for economic diversification, industrialisation and integrated rural development, the African Union considers the mining sector as an important pivot [1–3]. At the same time, land is a major means of rural livelihood as it is exploited to boost up agricultural, agro-based and non-agricultural production. While the perceived and real contributions of mining activities to economic diversification of African communities is well acknowledged [4–6], the major concern of civil organisations, stakeholders and individuals is the negative impacts of land degradation linked to mining sector activities [7,8]. Mining is a dominant land use activity that has the potential to degrade land resources [9].

Mining induced land degradation (MILD) will remain an important global issue in the twenty-first century because the global demand for metallic mineral commodities is predicted to increase in the coming years. About two-thirds of this demand is expected to come from South America, Southern Asia and sub-Saharan Africa [10]. Mining and its associated activities stimulate land degradation through removal of vegetation, topographic alterations, loss of top soil and soil compaction from use of heavy machinery. It is found that in mine sites, overburden removal results in significant loss of forest cover and nutrient-rich top soils [11]. Loads of removed overburden are normally piled within the mine lease area, and sometimes extending beyond the lease boundaries onto public lands.

However, the on-site and off-site explicit links between mining and land degradation are easily masked due to the dearth of research. Land degradation can be defined as a reduction in the capacity of land to support biological, chemical and economic productivity for its beneficiaries [12]. This results from a number of processes such as soil erosion. Removal of vegetative cover by mining activities exposes land surface to water erosion. Erosion by rain water is the dominant aspect of land degradation

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and difficult to manage in tropical countries, such as Ghana [13]. The major characteristics of land degradation by soil erosion include top soil displacement from origin, silting up of water bodies at destination, as well as gullies and ravines formation [14].

Several studies and reviews have demonstrated that land degradation, induced by both mining sector and other anthropogenic activities, affects both economic and non-economic facets of livelihood [15–17]. Lin et al. [18] found that the destruction of natural colonies of vegetation in the Guangdong Dabaoshan mining region of China has resulted in soil erosion by water. This event further led to soil acidification, affecting irrigational farming, grazing lands and food crops. Similar mining-induced erosional effects on agricultural production have been detected in the south-western and central mining regions of Ghana [19,20]. Studies show that there exists a strong relationship between magnitude of land degradation and high population density [16,21,22]). Thus, it is opined that economic land use and land degradation have strong location links with sustainability and quality of life [15]. Hence, a combination of exploration and mining activities and high population growth accelerate the rate of land degradation, leading to loss of rural livelihoods and associated resistance against the mining industry [23–26].

To avert conflicts resulting from mining-induced land degradation and livelihood disarrays, Eswaran et al. [15], El Baroudy and Moghanm [27] suggest assessment, monitoring and the use of mitigating technologies. To this end, geographic information systems (GIS) and remote sensing models are used to produce physiographic and socio-economic analyses of the studied area. Liu et al. [28] used vegetative cover and population pressure data in GIS to assess the severity of land degradation in Shaanxi province of China. They concluded that incorporating both physiographic and socio-economic data in GIS produced realistic assessment of land degradation risks. Townsend et al. [29] used geospatial tools to assess the spatial extents of mine land degradation and reclamation in the Appalachians mountaintop mining region of USA. The study found that among other implications, mining-induced land degradation would potentially affect watershed hydrology, forest loss and flooding hazards. Lutz et al. [30] also used geospatial tools to estimate the amount of mineral commodity produced per unit landscape disturbance in the US. Sahu and Dash [31] also analysed the potential impacts of overburden on adjacent land uses using GIS.

Land degradation caused by mining industry activities has been a subject of academic research in developing countries [13,32]. However, estimations and prediction of its extents and effects have largely remained in qualitative form. Few studies have assessed and quantified the potential vegetal disturbance in mining areas. Especially in emerging mining regions of sub-Saharan Africa, there are few adequate early warning indicators of land degradation linked with the mining sector. Although statutory agencies have been established in most countries to scrutinise the environmental and social impact assessments of mining sector activities, these agencies are confronted with logistics and technological constraints [9]. As a result, they lack benchmark indicators and baseline information for assessing the spatial extents, prediction of mining-induced land degradation and associated impacts. This underscores the need for detailed investigations, requiring new models and procedures.

The purpose of this study, therefore, is to develop early warning indicators of mining-induced land degradation to enable collaboration between stakeholders in new areas where exploration and mining activities are underway. To this end, the study develops models for quantifying the relationships between mining leases and biophysical conditions that enhance land degradation. The study further identifies the spatial distribution of potentially stressed systems and estimates the risks. This would enable researchers and stakeholders to estimate the socio-economic and environmental impacts of mining on local communities and link these changes to communities' resistance against the mining sector activities.

Materials and methods

Study area

Both industry players and the International Financial Corporations rank Ghana as a model country among mineral resource-rich developing countries [6]. The country hosts significant amounts of

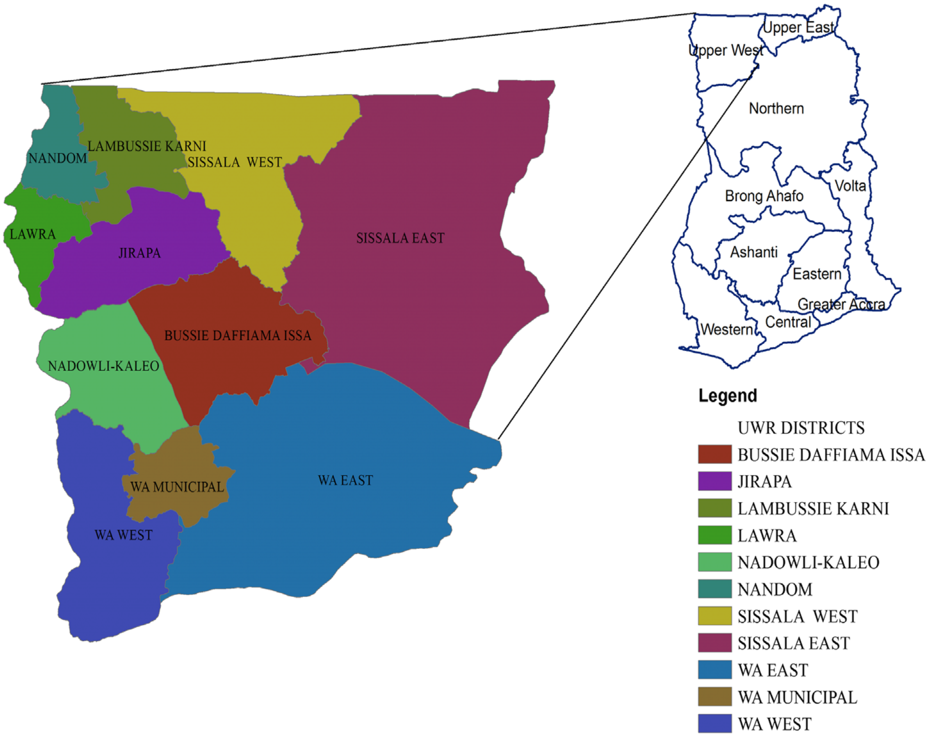

Figure 1. Study area

mineral resources including, gold, manganese, bauxite and diamond [33,34]. The gold mining sub-sector is the largest in terms of production and economic contribution. Whereas mining is a significant contributor to Ghana Government's revenues, the industry also accounts for land degradation in host communities [9,35]. In Ghana, the Northern and Coastal Savannas are the most affected areas. The World Bank [9] estimated that land degradation through soil erosion costs Ghana between 1.1 and 2.4% of gross domestic product annually.

Accra is the administrative capital of Ghana with nine other administrative regions across the country (Figure 1). The Upper West (UWR), Upper East, and Northern are the three regions in the north of Ghana. The country is divided into six agro-ecological regions, namely: Sudan, Guinea and Coastal Savannas; the Forest-Savanna transitional zone, semi-deciduous forest, and high rainforest zones with a land degradation index (LDI) of 6.56 [12]. The three northern regions cover the first three ecological zones referred to as the Northern Savanna zone. The zone is characterised by a single maxima rainfall regime, which lasts for five–six months. Rainfall is short, torrential and highly erosive in this area [13]. Average annual rainfall in the area ranges between 885 and 1100 mm and the average temperature is 28.6° [13]. The rainy season is followed by six–seven months dry season in the Northern Savannas. Vegetation of this area consists of ground cover grasses of varying heights, interspersed with fire-resistant, deciduous trees. Previously, Ghana's mining sector activities were concentrated in the south-west and central areas. However, recent discoveries of gold and other important minerals have redirected exploration and extractive activities to the Northern Savannas.

This study focuses on the UWR. It is the second poorest region in the country [36] which contains 11 districts, and the current study takes a closer look at those districts with mining interests. These are: Jirapa, Lambussie Karni, Lawra, Nadowli-Kaleo, Nandom, Wa East and Wa West. The 2010 Population and Housing Census (PHC, 2010) recorded 702,110 of human population for the UWR with an annual intercensal increase rate of 1.9% [37]. According to Oduro-Afriyie [38], the UWR is

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a moderate erosivity risk zone. Meanwhile, over 80% of rural households in this region depend on land resources for their livelihood [39,40]. Environmental Protection Agency (EPA) [13] indicated that the Wa–Lawra belt was most prone to land degradation and desertification. Hence, we assert that this study would provide a detailed account of the potential contributions of mining activities to the observed trends and patterns.

Data collection and preparation

This study makes use of both primary and secondary data. The Centre for Remote Sensing and Geographic Information Services in the University of Ghana developed the Ghana Land Use and Land Cover Classification Scheme. Details of the survey methods and algorithms used can be found in [41]. The scheme has been applied in all the ecological zones in Ghana. Land cover data from the scheme were obtained as shapefiles and used to estimate the average vegetative cover that would potentially be removed through exploration and mining activities. Note that the Land Use and Land Cover map also included number of tree stands in their database. Exploration lease (EL) maps granted in the study area have been downloaded from Azumah Resources website and digitised in ArcMap (http://www.azumahresources.com.au/projects-wa-gold.php). It may be noted that Azumah Resources currently holds exploration and mining leases in the area.

Mean monthly rainfall data have been obtained from the Ghana Meteorological Agency. The data cover varying years, depending on the availability of various meteorological stations in UWR. The stations where the data have been reported are: Nandom, Lawra, Han and Cherekpong. Data for Babili, Wechau, Tumu and Wa stations have been adopted from Adu [42]. Nandom station data cover 11 years; Lawra data span 24 years; Han data cover 14 years; Cherekpong data also cover 17 years. Tumu, Wa, Wechiau and Babili also cover 10, 40, 5 and 10 years, respectively.

A Polygon shapefile containing districts boundary has been obtained from the Ghana Statistical Service (GSS). However, Nandom and Nadowli-Kaleo districts have been digitised from historical maps. Nandom is one of the two new districts created in UWR in 2012 but is not available in digital form. Nadowli-Kaleo district is an old district that has been partitioned. Nandom district was formerly under Lawra district; and Nadowli-Kaleo district was Nadowli district. The coordinates used to train the digitisation were generated from the districts profile documents. The district profile is a summary document, usually prepared by the district assembly (DA), which describes the district's socio-economic and environmental features. The features were validated on the old districts' hardcopy maps. Coordinates were in the Ghana Metre Grid, which uses the WGS84 datum.

The PHC 2010 data of all districts in the study area were also obtained from the GSS. However, it has been almost five years since the data were generated. Hence, the annual inter-censual rate of population growth was used to estimate population figures for all the districts. This gives updated population figures for the entire five-year period since the data were first collected. Data on Crude Death Rate (CDR) for the UWR were also obtained from the GSS and used as poverty indicators in this study [37,43]. The CDR data are district specific and give a more comprehensive analysis of poverty in the area. Besides, the annual rate of decline in children under-five mortality rate (UfMR) in Africa is reported to be slow or almost not changed [44]. Specifically, Ghana's record for the baseline year, 1990–2008, has been unsatisfactory. For this reason, no CDR were used in place of infant mortality rate (IMR).

Two field visits were made to all the districts between December 2013 and February 2014; and December 2014 and March 2015. The purpose was to: (1) learn the objectives and mining aspirations of the districts; (2) map the existing state and causes of land degradation, and (3) document the patterns of land cover types in the districts. Participatory rural appraisal tools were used for field data collection. Overall, 30 purposive semi-structured interviews were conducted. Four local authorities from each district were individually engaged in a number of informal interviews. Thus, a total of 28 local authorities were engaged in 28 semi-structured key informant interviews. Authorities engaged include district environmental planning and agriculture officers. A qualitative description of the districts'

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environmental situation is contained in the district profiles. Two regional project officers of the EPA were also involved in informal discussions regarding results obtained from the districts. This helped validate the results obtained from the field as well as asserting the results obtained by the analysis.

Data analysis

Exploration/mining-induced trees and shrubs' displacement

For each district, the mix of land cover determines the average number of trees that are feasibly displaced by mining sector activities (Figure 2). The total vegetal cover potentially removed in each district was estimated using the Ghana land use/land cover data derived from satellite imagery [41]. However, the unit of measurement was a challenge in this case. Whereas grasses and herbs can be measured in kilograms (kg), trees cannot be measured as such. For this reason, both estimates have been isolated. However, a combination of their individual estimates can give an efficient impression of the potential displacement of vegetative cover and erosion risks. There is a dearth of existing models for quantifying mining-induced vegetation displacement. Hence, the following models have been developed and used in this study to estimate potential vegetation displacement within approved mining leases:

$$—\mathrm{EstNT}_{\mathrm{qm}} = \left[\sum \mathrm{EstNT}_{\mathrm{qELm}}\right] \tag{1}$$

$$\mathrm{EstNT}_{\mathrm{qm}} = \mathrm{TrDens}_{\mathrm{q}} \times \mathrm{Area(A)}_{\mathrm{am}} \tag{2}$$

where (—) is the displacement; EstNT is the estimated number of trees; q is the land cover type ; m is the location (district); and TrDens is the tree density.

$$-\mathrm{F}_{\mathrm{mt}} = 2170\,\mathrm{kg} \times \mathrm{EL}_{\mathrm{Am}} \tag{3}$$

where F is the Forage and herbs under trees; t is the season; A is the area of; and EL is the exploration/mining lease.

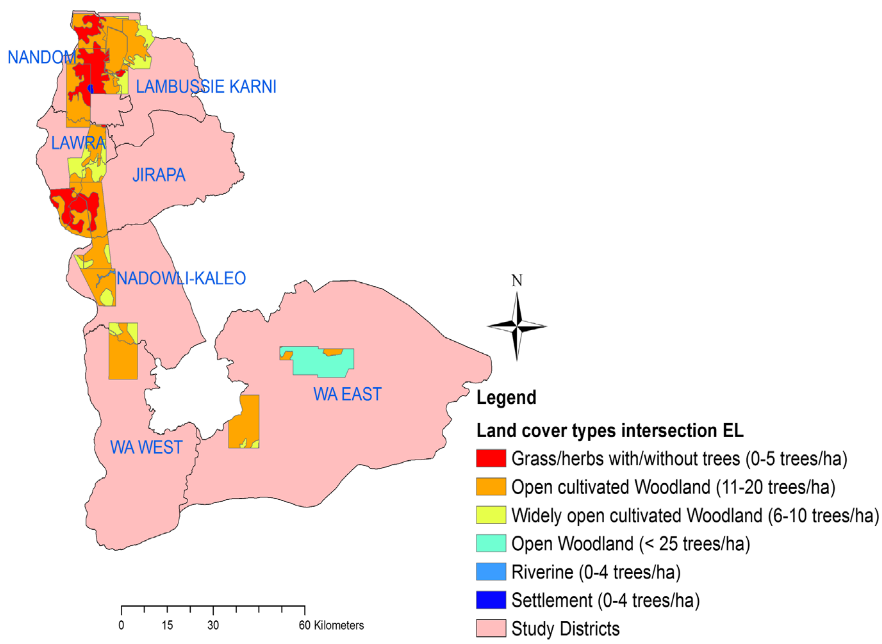

Figure 2. Land cover under Exploration/Mining Leases (EL)

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The estimated number of trees per land cover and land use type in each district has been measured by multiplying the tree density per land cover class by the amount of area occupied by the land cover category in a district. The tree density per land cover has been taken as the median of the range of trees' occurrence in each class. For example, a land cover with values between 6 and 10 will have 8 as the tree density per hectare (ha) (Figure 2). The median is used because within the same land cover, there can be spatial variations in tree stand. Some areas have more trees than measured in the data while other areas tend to have fewer trees than measured. This was observed during the fieldwork. Where the data give an open value, the median is calculated by perching a range between the highest values of a given land cover type with the lower class value or upper class value of the next land cover type. For example, land cover with a value of >20 has a next lower value of <25 in another land cover type. Therefore, the median value would be 22.5 trees/ha. Thus, the estimated number of trees potentially displaced in each district is the sum of the number of trees per land cover per exploration lease (EL) in that district. There is no data on above ground biomass estimates in the study area. Estimated forage per hectare in the Northern Savanna is 2170 kg [45]. This was adopted and used in Equation (3) to cater for the grasses and shrubs that occur under tree cover.

Land degradation impact index

To calculate the land degradation impact index (LDII), the potential mining-induced LDI is first computed. No existing expressions for assessing mining-induced LDI were found. Therefore, the following expression has been developed in this study to fill the gap: Equation (1)/EL_{Am}, that is, the estimated number of trees potentially removed per unit area of ELs in a district. A pseudo-stripping ratio was also measured using the amount of grasses/shrub potentially removed per unit area of landmass within an EL in a district. These parameters have also been measured within existing mine operation areas (MOPAs) in Wa East and Nadowli- Kaleo districts. The LDI and poverty indices are used together with the corrected rural populations for all districts to measure LDII. Due to lack of models, the LDII expression below is adopted from the Global Land Degradation Index Systems (GLADIS) [12] and used in this study:

$$\mathrm{LDII} = \left(\mathrm{LDI} \times \mathrm{adjusted}\left(\mathrm{RuPop}\right) \times \mathrm{CDR}\right) \tag{4}$$

where LDII is the land degradation impact index; LDI is the land degradation index; RuPop is the rural population; IMR is the infant mortality rate; and CDR is the crude death rate.

The LDII for any period of a mine life span can be predicted by adjusting the population and poverty-level figures to reflect the base period's data, that is, if the current data for that period are not available from the census bureau. In this respect, this study predicted the LDII for the first six years of an exploration and mining licence granted in the study area. Exploration and mining licences are often granted for 15 and 25 years in Ghana [46,47]. However, these are subject to renewal after every four to six years of operation. LDII has been calculated using the district specific CDR values. Likewise, Mine6yrs refers to six years of a potential mine operation and has been calculated using the CDR values. The CDR values cover all years including IMR and uner-five mortality rates (UfMRs). However, IMR and UfMR have been the most widely used poverty indicators [12,48].

The population data were used to measure the population densities of all districts to set benchmarks for measuring mining-induced population pressure on land degradation. It was also done to test the hypothesis that land degradation impacts are more pronounced in areas with high population densities. These population densities were then intersected with the LDII results.

Rainfall erosivity index

Rains in the Northern Savanna usually start between late April and early May and intensify between July and October. The peak periods of the rains occur in August and September (Figure 3). These rains usually have high kinetic energy enough to remove land surface [13,49]. The mean annual rainfall data, from long-term meteorological record, were computed and used to calculate the rainfall erosivity

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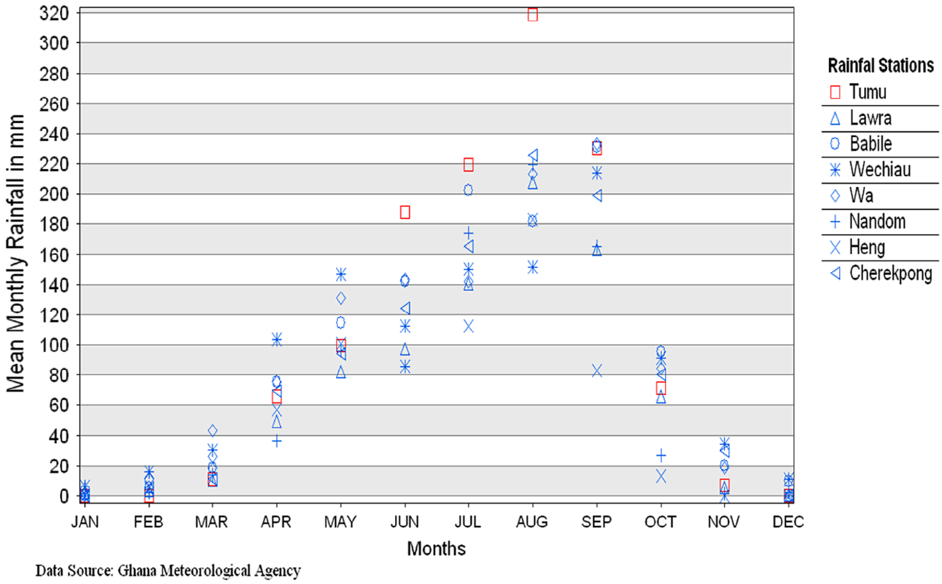

Figure 3. Mean Monthly Rainfall across all stations

indices for the study area. The Fournier [50] coefficient (F_m) approach below has been used to calculate the rainfall erosivity index as:

$$F_m = \sum_{i=1}^{12} \frac{P_i^2}{P_{ANN}} \tag{5}$$

where P is the precipitation; *i* is the month with the highest record of precipitation; and P_{ANN} is the mean annual precipitation.

Using Hudson [51] erosivity index of >25 mm as cut-off value, the study area can be classified into low to severe erosion risk zones. The Fournier co-efficient has been used due to its appropriateness for calculating the erosivity index in tropical regions [12]. Oduro-Afriyie [38] used the F_m to develop a rainfall erosivity map for Ghana. However, this map cannot be used for assessing erosivity risks at the district and village levels due to its coarse resolution.

Iso-erosivity mapping

Therefore, this study had to develop a high-resolution Iso-erosivity map for UWR, using GIS. The results from the F_m were joined to point shapefiles of corresponding meteorological stations. The point shapefiles were then used to create a triangulated irregular network (TIN) using the indices field. The TIN was then converted to raster and finally, a contour tool was used to develop the Iso-erosivity map of the study area, with a 5-mm interval.

Results

The results of vegetation removal in Figure 4 show that for the mining concessions in Nadowli-Kaleo and Wa East districts, a minimum of 225 trees and 24,827 kg of herbage have been displaced. In the other ELs, a minimum of 2432 trees and 22,9019 kg of herbage can potentially be displaced. Nandom district had the highest potential vegetation cover removal and Wa West district had the least. This is because Nandom district has the largest ELs. However, during informal discussions with

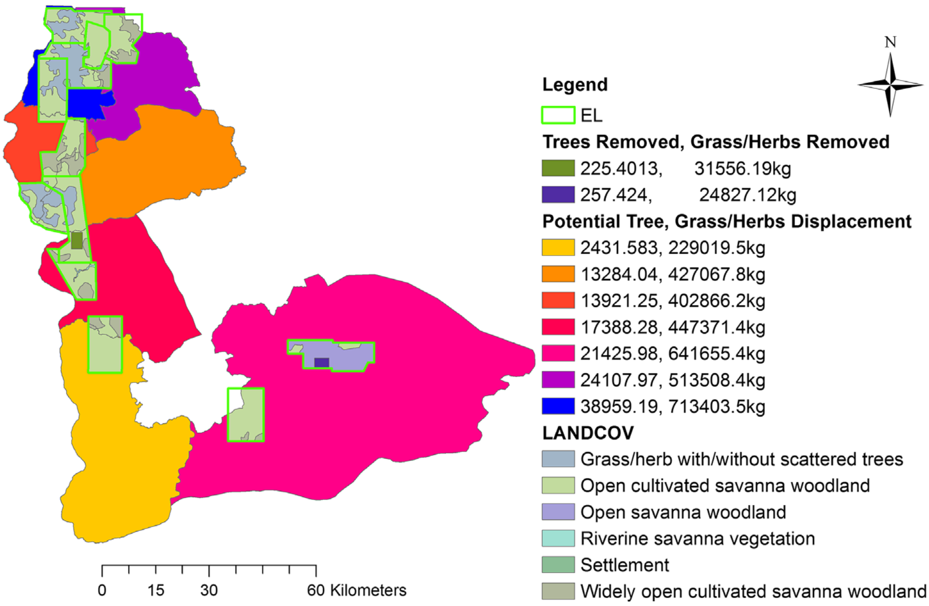

Figure 4. Estimated Current and Potential vegetation displacement

the exploration company, it was stressed that part of the leases granted in the Nandom district shall be released to small-scale miners. Nonetheless, small-scale miners would equally be displacing trees and grass cover.

Analysis of land degradation potentials in the current MOPAs in Wa East and Nadowli-Kaleo districts provides LDIs of 0.22 and 0.16, respectively. Using the LDI thresholds of GLADIS [12], <0.25 means low degradation potential; 0.25–0.49 means moderate; 0.5–0.75 is strong, and >0.75 is bad degradation index. In Figure 5, the minimum LDI is 0.02, which is in the Wa West district. Nandom district records the highest LDI of 0.8, followed by Lambussie Karni and Lawra districts with 0.31. Thus, apart from Nandom district, the rest of the areas would experience moderate to low mining-induced land degradation events. Analysis of grasses and shrubs' stripping ratio also shows 21.7:1. This implies that for every unit of land surface stripped for mining activities, a minimum of 22 kg of grasses and shrubs would be displaced within each MOPA. Table 1 shows that every unit of land surface stripped for exploration and mining would disturb a minimum of 1.53 kg of grasses and shrubs.

Table 1 also shows the current state of land degradation impacts in the study area. These are represented as LDII. The results indicate that with the CDR computations, Nandom district records the highest LDII of 322, about 0.75% of its rural population. Wa West district records the lowest LDII of 13, about 0.01% of its rural population. Figure 6 provides a visualisation of the land degradation impact indicators. Except Wa East district, areas with moderate to significant LDIIs also have high population densities (Figure 7). Wa East district has population density of about 19.4 people per km^2. Lawra district is the most densely populated area with a density of 135 persons per km^2. Again, the Nadowli-Kaleo in the central portion has moderate population density (62/km^2). These results have implications for sustainable mining in the area.

The rainfall Iso-erosivity map (Figure 8) shows the potentials of soil erosion by water in the study area. The Isolines, running from north to south across the focus area of the study indicate areas of equal erosivity index. The study's focus area falls between 42 and 80 mm of the Isolines. That is the Wa-Lawra belt and the Wa East area. The east, including Wa East district, has the highest index of 84 mm recorded at the Tumu station. The indices of the western portions of the study area range between 42 mm in the southern portions of the Wa West district, and 70 mm within Lambussie Karni district in the north.

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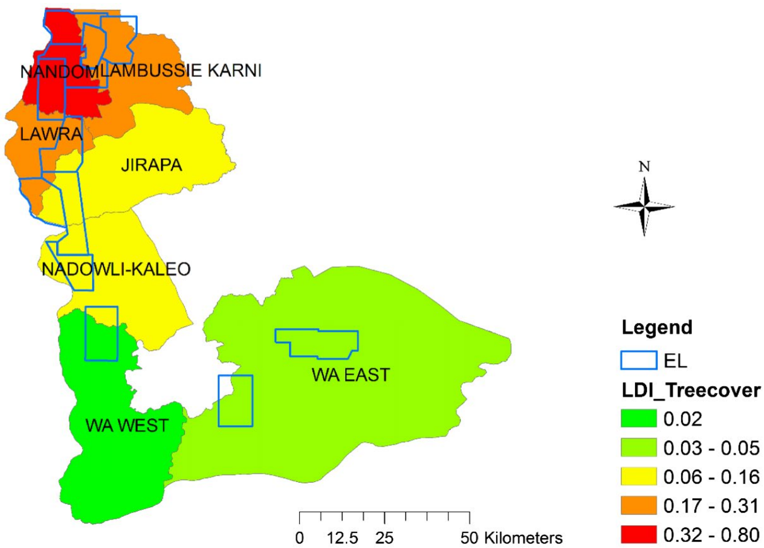

Figure 5. Potential mining-induced LDI

Table 1. Showing LDII and potent Grasses/Shrubs Stripping.

District	Shrub strip	LDII	Percent (%)	LDII Mine 6yrs	Percent (%)
Wa West	1.53	13	0.01	79	0.09
Wa East	1.58	44	0.06	264	0.33
Nadowli-Kaleo	4.13	129	0.19	773	1.15
Jirapa	3.59	98	0.12	589	0.71
Lambussie Karni	6.60	173	0.35	1040	2.12
Lawra	9.09	158	0.30	949	1.79
Nandom	14.61	322	0.75	1929	4.50

Notes: CDR: Crude Death Rate per 1000 of Population; LDII: Land Degradation Impact Index

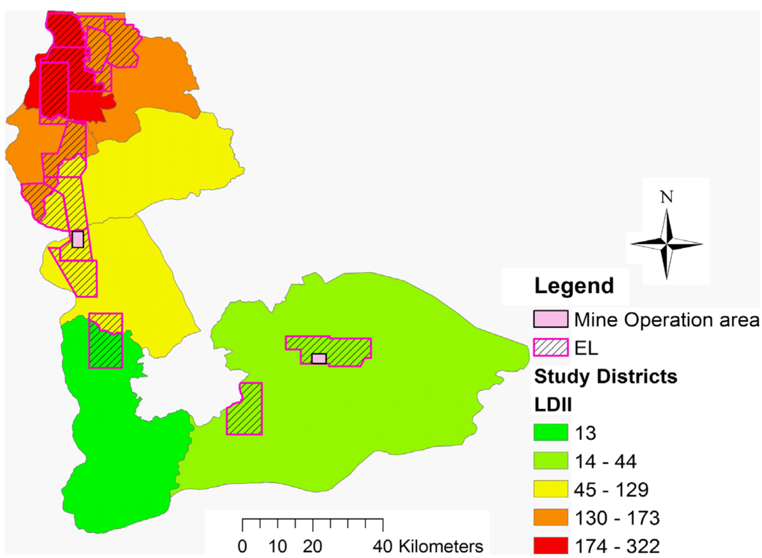

Figure 6. Potential mining-induced LDII

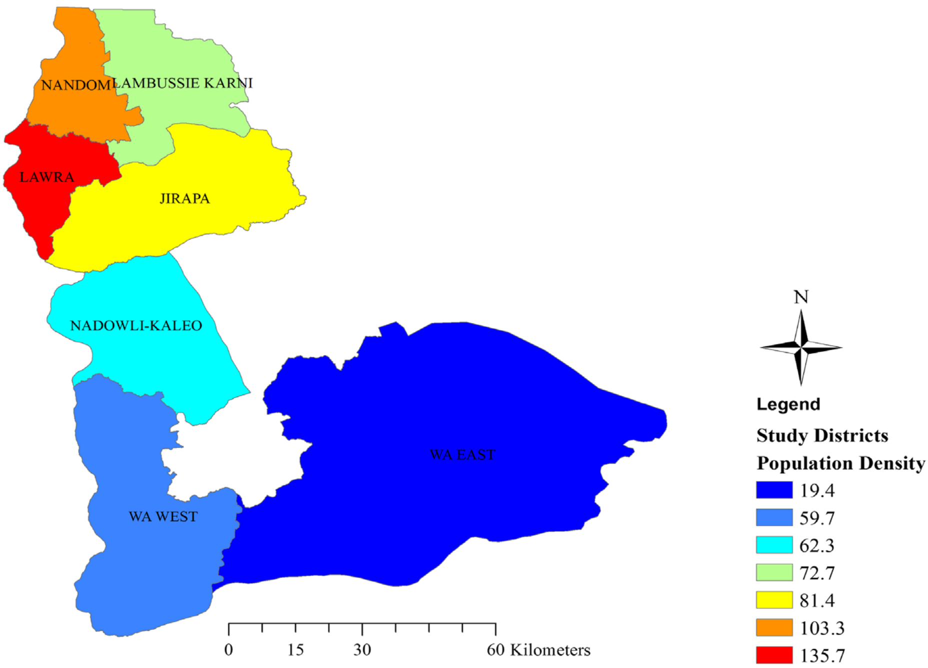

Figure 7. Population density per district

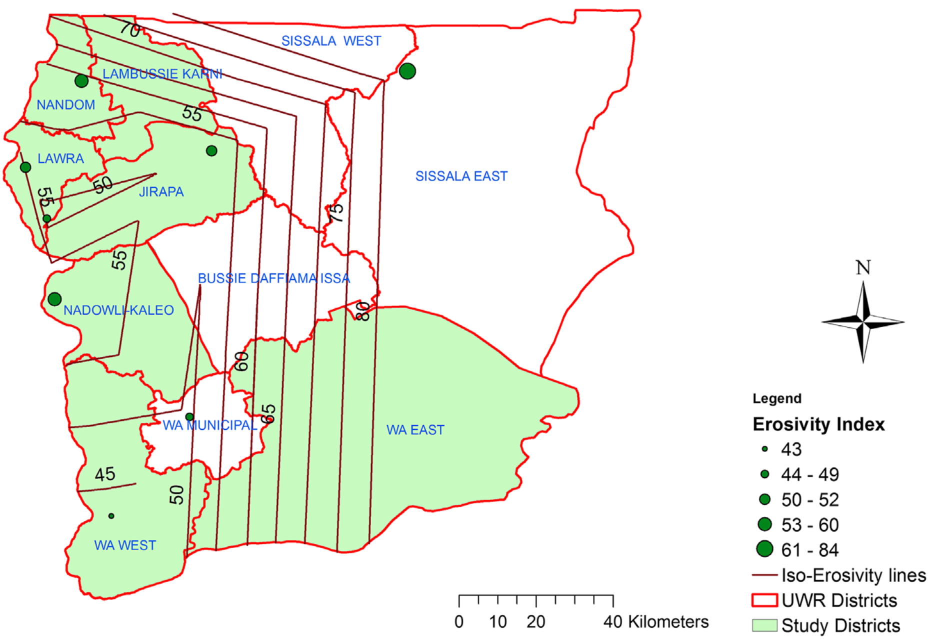

Figure 8. Rainfall Erosivity map of study area showing Iso-Erosivity contours

The central portion in the west, around Jirapa, Nadowli-Kaleo and Lawra districts, however, range between 50 mm and 55 mm. North-west of Nadowli-Kaleo and around the central portions of the Wa East districts fall within 55 and 80–85 mm. These areas currently host mining leases.

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Discussions

It is observed that the ELs in the Wa East district cover open Savanna woodland, with tree densities between 20 and 25 per hectare (Figure 2). Thus, the size of the ELs covers large tree densities and herbage, implying large tracts of vegetal removal by mining activities in the district. Another observed pattern of land cover across the ELs, west of the study area, is that they are dominated by grass land and open cultivated Savanna woodland (Figure 4). This was also noticed during fieldwork. The Nandom district is located in this part with more ELs granted than it can support. Hence, the district is more susceptible to the highest number of tree and grass cover potential displacement. Within the ELs in particular, Nadowli-Kaleo district also contains open cultivated Savanna woodland. Schreckenberg et al. [52] found that there is a negative correlation between cultivated lands and tree density. That is, an increase in cultivated lands leads to a decrease in tree cover. This explains why the Nadowli-Kaleo district records the minimum number of trees and a higher amount of grass cover, altogether removed on the mine operation site. Coupled with land cover, the number of leases granted in the western corridor of the study area is modifying parameters to sustainability issues. These together make the area more vulnerable to MILD, especially Nandom district (Figure 5).

The results of LDII (Figure 6), as investigated in this study, support the findings that the impacts of land degradation are more intense in areas with high population densities [21]. Lawra and Nandom districts, being the most densely populated areas, have higher LDIIs than the rest. The densities may explain trends of rural settlements in the districts. From interactive discussions with local authorities during fieldworks, it was found that the capitals of both Lawra and Nandom districts are urbanising with populations over 5000. All other localities have less than 1000 populations. Moreover, due to agricultural failures in rural settlements, the commercially oriented district capitals tend to pull rural populations. Also, Lawra, Nandom and Jirapa have better infrastructure than all the other district capitals, especially Wa East. This explains that the impacts of mining-induced land degradation would be severe in the densely populated areas of Lawra, Nandom and Jirapa districts than Wa East and Nadowli-Kaleo districts.

The LDIIs are calculated within the first year of the mining industry operations. This has been projected within six years from 2015 but could exacerbate if sustainable land management mechanisms are not put in place. Whereas Jirapa, Lambussie Karni, Lawra and Nandom districts are urbanising, Wa West, Wa East and Nadowli-Kaleo are typically rural. With the introduction of mining and its subsidiary activities, there will be demand for land to provide accommodation, feeding and energy for immigrating populations in the Wa East and Nadowli-Kaleo districts. It was found during fieldworks that already about 90–100% of biomass energy consumption in rural Northern Savannas is from firewood and charcoal. This means the rate of biomass consumption would be more than double since demand will increase, and more wood from trees would be removed to meet the incipient demand coupled with on-site and off-site displacements. This has negative implications for agriculture, resettlement and other socio-economic activities in the area. It is suggested that poverty trends are more pervasive in rural areas than in urban areas in developing countries [36]. Thus, marginalisation of existing land use activities and rural livelihood due to MILD in the landscape could result in public resistance against the mining sector activities in the area.

The erosivity indices (Figure 8) obtained from this study largely disagree with the generalisation of Oduro-Afriyie (1996). Whereas Oduro-Afriyie used data from only one meteorological station (Wa) to obtain 45 mm as an index for the entire UWR, this study used data from eight meteorological stations from almost all the districts in UWR and obtained district-specific erosivity indices. Except the results of Wa and Wechiau stations, indices obtained from all the other stations vary significantly from Oduro-Afriyie's index. This shows the spatial distribution of erosion risks across the UWR. The variances in the indices also reflect on the Iso-erosivity map developed in this study and that of Ghana developed by Oduro-Afriyie [38]. Oduro-Afriyie's classification scheme puts the entire UWR as a moderate erosion risk area, whereas this study found disparities in the erosion risk levels across the UWR. It is found in this study that the west of Nadowli-Kaleo, east of Jirapa and Lambussie Karni districts are within the severe risk zone. Wa East and Sissala East districts are in the very severe erosion risk zone. This has daring implications for mining land use. However, the middle portions of the Wa–Lawra belt agree with that of Oduro-Afriyie. Nonetheless, this status can be compounded considering the amount of vegetation potentially removed by the mining sector activities.

Conclusion

This study, first of its kind, quantified and mapped the existing and potential effects of land degradation due to mining industry activities. The potential mining-induced LDI ranges between 0.02 and 0.8, inclusive, across ELs in the study area. However, LDI is between 0.16 and 0.22 within MOPAs in the two districts currently hosting mining activities. The LDI impact indices show that a minimum of 13 and a maximum of 322 people would be affected per unit area of mining-induced degraded lands in the study area. Thus, the Iso-erosivity map developed in this study enhances a visual perception of the risks. The map shows that most of the mining leases are within 45–60 mm, which is a high erosivity risk. It is, therefore, curious that most of these areas would also host the incipient populations attracted by the mining sector activities. Hence, these results would help raise the awareness of policy-makers, communities and interested development partners regarding the need to find efficient strategies for sustainable mining and mutual beneficiation of rural land resources. The findings would further enhance companies' and governments' understanding of the links between MILD and social conflicts [53]. Preventive research actions at the onset of mineral resource prospection and exploration are encouraged for vulnerable tropical environments [9,16]. Quantifying and predicting the environmental and social uncertainties from the outset will enable planners to strategise local space. The African Union [7,8] indicates its commitment to coordinate policies and programmes of member countries, aimed at addressing land degradation issues. These countries, including Ghana, can use these findings to review their policies in this direction. The results also provide benchmark indicators for monitoring and assessing the mining industry activities [13]. This study prepares a benchmark for a more comprehensive research on mining induced land degradation and displacement in Africa.

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CHAPTER 7 Potential Mining-Induced Water Stress (MIWS)

This Chapter is covered by the following publication:

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This chapter assess the potential effects of exploration and future mining activities on the quality and quantity of water for any use in local communities. Land degradation further undermines water availability & quality through downstream pollution and reduction of vegetation to contribute to the water system. Vegetation cover augments the water regulation service of land, and its efficiency in intercepting rainfall determines the capacity and availability of both ground and surface water for human use (Sophocleous 2002). Water is a vital resource for mining and minerals production. Therefore, the protection and efficient use of water systems by newly introduced mining activities in an area determines the allocation of rainwater, groundwater and surface reservoirs for primary production; irrigation, livestock watering, Shea butter production and other domestic uses (Dregne 2002; Toledano and Roorda 2014).

However, exploration and mining activities account for an occurrence of land degradation and their associated damages; soil erosion, reduced groundwater recharge, excessive clay and silt loads in downstream water bodies (Mbaya 2013; Zhao et al. 2013). Thus, water use regulation is of major significance to the relationships between the mining industry and local communities; and even between countries within shared water systems. As the movement of water also responds to gravity; from highland areas to low-lying areas, over abstraction downstream would increase the swift movement of water from upstream reservoirs (Sophocleous 2002). Thus, ground and surface water systems upstream would respond to the sucking effect of mining operations downstream and, for that matter, would be unavailable in normal quantities for upstream users. The ability to store water in natural aquifers would equally be affected upstream. The only difference between upstream and downstream local users would be contamination, which would move downwards.

Hence, in this chapter, the study postulates that the mining industry, as a large consumer and polluter of water systems, can initiate water stress if none existed or worsen an existing situation, thereby, stimulating social disruption and dispute (Toledano and Roorda 2014). Examples of conflicts emanating from mining related water pollutions are discussed by (Singh, Koku and Balfors 2007; Budds and Hinojosa-Valencia 2012; Bebbington and Williams 2008). Thus, households and people impacted by potential mining-induced water stress was calculated by adopting and modifying the land degradation impact index model of Nachtergaele et al. (2010)

and the WHO (2010) World health statistics 2010, using contextual parameters. Example: GWSI for domestic users was calculated using the populations of households that use groundwater for drinking; and the GWSII is calculated as such.

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Original article

Investigating potential mining induced water stress in Ghana's north-west gold province

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ABSTRACT

This study investigates the potential interactions of mining industry activities with water sources. The investigation identifies the socioeconomic impacts, as demands for water for domestic and industrial purposes are expected to increase. A case study was conducted in Ghana's North-West, one of the country's emerging gold provinces. Data were obtained from both primary and secondary sources. Socioeconomic and mean monthly rainfall data were integrated with data on 124 boreholes, and locations of 45 dams and ponds. The criticality ratio was modified and used to estimate groundwater stress indices (GWSI) for the region. A minimum of 0.008 and a maximum of 0.016 groundwater stress indices were obtained. Aridity indices were also estimated and used to develop an iso-aridity map for the area. It was found that a maximum of 229 and a minimum of eight rural households would potentially be affected due to growing water stress. With the emergent use of water in mine operations, conflicts may arise between local communities and companies, and between neighbouring states. The results of this study provide baseline information that could be useful to stakeholders for informed decision-making and the management of mining-related water use conflicts in developing countries.

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1. Introduction

The spatial interactions between the increasing numbers of mineral resource development projects in Sub-Saharan Africa, and sources of water for domestic and industry uses are intricate. The character and fate of water resources in sub-Saharan Africa are shaped by its growing human population, residential expansions, and attendant land development. This has increased the demand for water, leading to stress on scarce sources. Water stress is defined as the reduction in the capacity of water resources, both underground or surface, to support physical, chemical or biological production for domestic, industrial and commercial purposes (UN-Water, 2009). This leads to water scarcity or the inability of sources to meet societal demands (UN-Water, 2007).

Water scarcity is among the most critical environmental problems in the twenty-first century. According to the United Nations Thematic Water Initiatives (UN-Water, 2007), approximately 1.2 billion people across the globe, mostly in developing countries, live in 'water scarce' areas. It is further projected that a further 500 million people will be at risk of water scarcity in the near future (UN-Water, 2007). Furthermore, approximately 1.6 billion people face water stress in countries where there is lack of capacity to take available water from remote rivers and aquifers, for purposes other than domestic usage (UN-Water, 2007). Further studies show that inhabitants of over 67% of rural communities in sub-Saharan Africa have no access to potable water sources (Assessment, 2005; UN-Water, 2015).

Water stress is caused by two main processes: natural and anthropogenic. Natural processes include climatic, physiographic, biological, and geological aspects of the environment (Peters and Meybeck, 2000). Natural disasters such as earthquakes, volcanic eruptions, landslides and floods can impact the availability of water and may lead to water scarcity. Anthropogenic processes, however, alter the rate and frequencies of these natural processes. Resource creation, via urbanisation, agriculture intensification, and mining activities, is the major anthropogenic factor that may initiate water stress. During resource creation, man modifies the landscape, potentially reducing its capacity for water sources and pathways at different spatial scales, and thereby degrading the quality and accessibility of the source. In addition, the quantity of available fresh water has a direct link with its quality. Once the quality of water is degraded, it becomes difficult to use for domestic, commercial and industrial purposes, particularly in arid and semi-arid areas (Peters and Meybeck, 2000). Agriculture and

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mining are the major anthropogenic activities that degrade water (World Bank, 2006). The negative impacts of agriculture on water stress have been discussed elsewhere (Peters and Meybeck, 2000). The impacts of mining industry activities on water stress, if not properly understood and managed, could also be pervasive, affecting not only local flow but also eventually regional flow systems (Sophocleous, 2002).

Due to the effects of substantial water use in mining operations, water stress and water-related conflicts may become inevitable in the associated regions. The UN-Water (2007) shows that shared ground and surface water systems could be a source of international governance cooperation. However, depletion of shared water systems, through mineral resource extraction, can be a source of conflict between neighbouring countries. For example, whereas Chile claims exclusive rights to the use of river Silala for copper mining, Bolivia argues for a mutual use and seeks to limit the activities of Chile's copper mines on the river (Toledano and Roorda, 2014). Another example is the dispute between the Netherlands on one hand, and France and Germany on the other, over pollution of the Rhine river (Haftendorn, 2000). The Rhine River serves as a major source of drinking water for communities in the Netherlands, and the quality of potable water was at stake.

In addition, contamination of both ground and surface water can also result in conflicts between local communities and companies. For example, Bebbington and Williams (2008); Lin et al. (2005); Miranda and Kool (2003) found that the contamination of up and downstream water sources from mine water and acid drainage resulted in company-community conflicts in Peru, Southern China, and Papua New Guinea. Akabzaa et al. (2007) find in Ghana that surface waters were more exposed to pollution than groundwater. Besides, Mol and Ouboter (2004) find a link between stream-bed sedimentation in the Amazon drainage system and water-driven erosion that is caused by mining. Moreover, Company-community conflicts also result from the diversion, over-abstraction or stemming of water bodies by mining companies. For example, mine expansion and intensification of low grade ore extraction has led to the over-withdrawal of water from 852 rivers, 1181 lakes, and 2277 springs in Mongolia (Toledano and Roorda, 2014). Instances of company-community clashes because of water stress are also reported elsewhere (Comment, 2013).

Nevertheless, little geographic information exists to adequately appraise and understand the extents of Mining Induced Water Stress (MIWS) on local communities in sub-Saharan Africa. While Environmental Impact Assessments (EIAs) are in place in developing countries, the nature and amount of water resources for use by local communities and their spatial interactions with the mining industry's activities is poorly understood by governments, and local stakeholders. Likewise, not many studies have measured the cumulative social impacts of MIWS for mitigating potential conflicts as this study does.

The purpose of this study, therefore, is to understand the spatially-explicit interactions between mining industry activities and water sources. It identifies the potential socioeconomic impacts that may result as the demands for domestic and industrial water requirements increase. Specifically, the paper aims to: (1) provide an overview of water stress status in the study area; (2) assess the potential impacts of the mining industry's activities on water sources; and (3) provide a robust prediction of potential company-community conflicts and inter-state conflicts due to resource extraction in shared drainage basins.

2. Materials and methods

2.1. Study area

Ghana is a mineral rich country in Africa. The country is bordered by Burkina Faso, the Republic of Togo, the Gulf of Guinea, and Ivory Coast (Fig. 1). It has 10 administrative regions and Accra is the capital. The three administrative regions in the north of the country are: Upper East (UER), Upper West (UWR), and Northern (NR). Mean annual rainfall, temperature, and humidity across all these regions are 885 mm, 28.6 °C and 54%, respectively (EPA, 2003). The Potential Evapotranspiration (PET) in the three northern regions is between 1652 mm and 1720 mm, with an annual aridity index of 0.54-0.60 (EPA, 2003). Excepting the district in the north-eastern corner, all three regions are within the Guinea

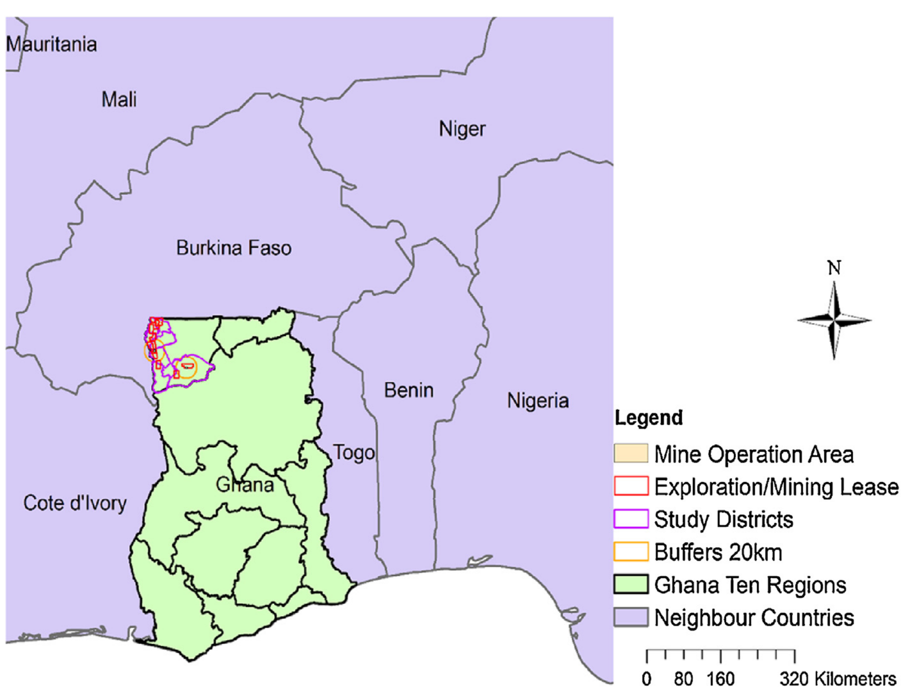

Fig. 1. Location of study area.

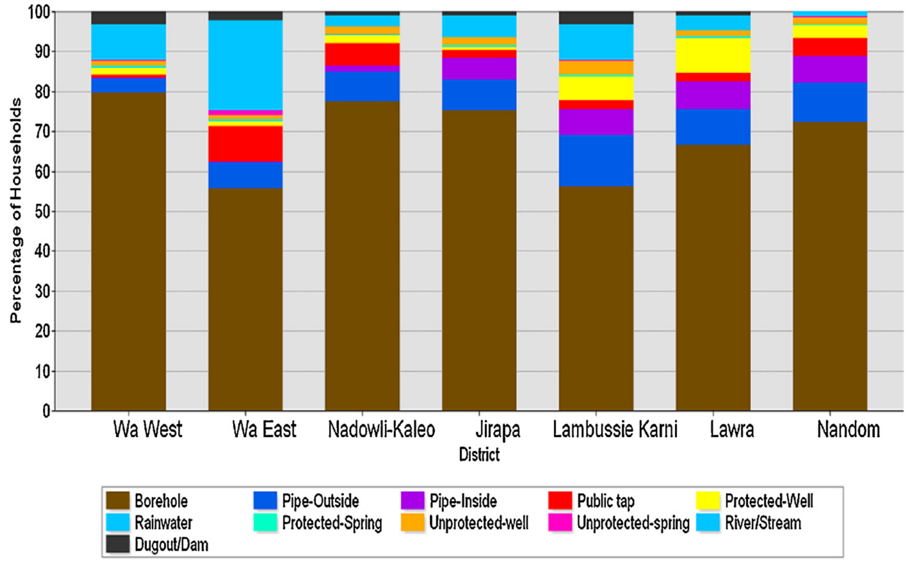

Fig. 2. Household source of water for drinking purpose.

Savannah agro-ecological zone, known as the Northern Savannah. Due to high annual kinetic energy loads of rainfall events, the area has been classified as moderate to severe soil erosion risk (Oduro-Afriyie, 1996). The vegetation consists of grassland of varying heights, interspersed with fire resistant, deciduous, broad-leaved trees. However, in areas around the northern borders with Burkina Faso, the vegetation consists of open grassland, widely-spaced shorter trees, fringe forests and woodlands or riverine areas along streams and river courses. The dominant geological units in the Northern Savanna regions of Ghana are those of the Birimian sequence and associated granites (Griffis and Agezo, 2000). The Birimian sequence is the source of most of the mineral deposits in the West African craton, including Ghana. This geological feature underlies areas west to north of the UWR, protruding into neighbouring Burkina Faso. For this reason, mineral resource development is becoming a new water-use activity in this part of Northern Savanna.

This study investigates the mining industry's activities in eight of the eleven districts in UWR. These districts are: Jirapa, Lambussie Karni, Lawra, Nadowli-Kaleo, Nandom, Wa East, and Wa West. The major sources of water in the region are: rainfall, rivers, streams, lakes; boreholes, wells, dams and dug-outs (Fig. 2). The main river basin in the UWR is the Volta Basin. This comprises the Black Volta and the Kulkpong rivers, connecting to the White Volta through the central portions of the Wa East district. Except for the Black Volta, streams, rivers, and dams are rainfed and often dry up during dry seasons. Therefore, the little water that remains in dams and dug-outs is mostly used for dry season farming and irrigation, and also for domestic use in both rural and urban communities. During the dry season, the most reliable source of water for domestic use is groundwater from hand-dug wells, boreholes, and is pipe-borne from treated plants. Hence, it is necessary to identify the inherent relationships between emerging mining industry activities and their implications for sustainable water use in this area, given the regional water requirements for the dry season.

2.2. Data collection and preparation

The population and socioeconomic data for all districts in the UWR have been obtained from the Ghana Statistical Service (GSS). This data covers the 2010 Population and Housing Census (PHC 2010) and were interpolated using the annual intercensal growth rate of 1.9% (GSS, 2013). Data on the sources of water for any usage at the district level (Fig. 3) were also obtained from the GSS. Mean monthly rainfall data were obtained from Ghana Meteorological Agency (GMA). UWR has meteorological stations in almost all districts. Data were available for variable periods for the following stations: Cherekpong, Babile, Nandom, Han, Lawra, Tumu, Wa, and Wechiau (covering 17, 10, 11, 14, 24, 10 and 40 years, respectively). However, due to their unavailability with GMA, rainfall data for Babile, Wa, Wechiau, and Tumu were sourced from (Adu and Asiamah, 2003). The chosen locations of meteorological stations were instrumental in generalising the rainfall data and for estimating and interpreting the aridity indices of the UWR.

Two fieldwork trips were conducted from December 2013 to February 2014; and from December 2014 to February 2015. This time of the year is the off-farming season where communities and fields are accessible and the feeder-roads that dominate this area are mostly trafficable. The objective of the fieldwork was to examine the sources of water for both domestic and other usage in the study districts. Fifty Villages were sampled based on: (1) their location within the Exploration Leases; (2) proximity to exploration drill holes; and, (3) kinship and social relationships, which were to be considered as part of the potential cumulative impacts of exploration and mining activities in the area. In total, 90 borehole locations were collected from the field. Boreholes were identified in each village through participatory mapping: community members were asked to indicate on sketch maps the relative locations of sources of water for drinking and other domestic purposes. These locations were geo-referenced using a handheld GPS with a 5-m positional accuracy. GPS coordinates of 34 additional boreholes were also obtained from Ghana Water and Sewerage Corporation (GWSC), giving a total of 124 borehole locations. Coordinates of a total of 45 dams, dug-outs, springs, and ponds were also taken at villages where these existed. Due to resource constraints, borehole locations could not be inventoried in the Wa East district.

Although the Black Volta is the only perennial river in the study area, seasonal streams and rivers are necessary inclusions for spatial analysis of water sources in the study area. These have been captured using the ASTER Global Digital Elevation Model (GDEM, v.2). Four tiles of GDEM datasets, with 30 m resolutions, were obtained from USGS and mosaicked in ArcGIS to cover the entire

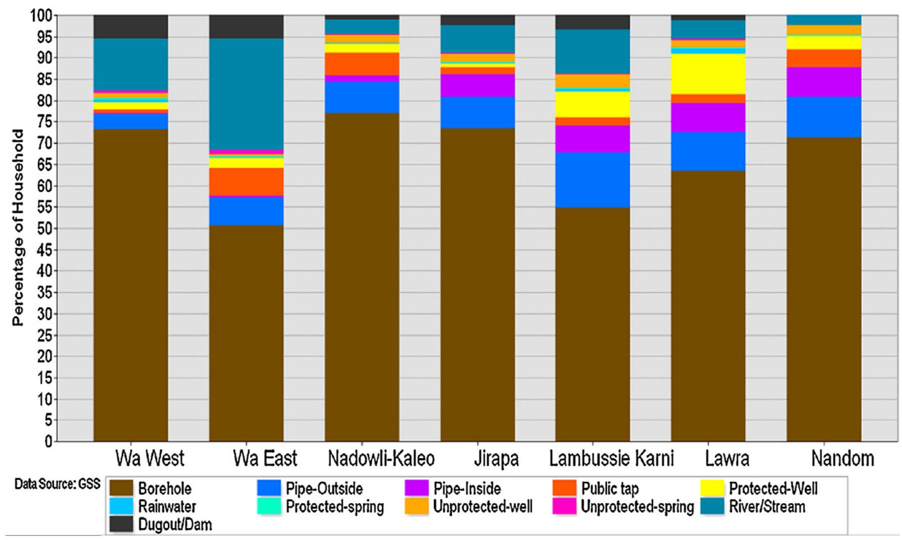

Fig. 3. Household source of water for other domestic usage.

UWR region. The GDEM was then clipped to the area of interest and used to develop the stream network and drainage basin of the study area. The USGS products are normally geometrically corrected from source. However, topographical corrections on the GDEM were necessary, to ensure that sinks were filled and that there was continuity in the drainage network. The minimum pixel value was 130 and the maximum was 461, indicating differences in elevations.

Polygon shapefiles of the study districts were obtained from the GSS. However, there were no existing maps for the newly-created districts. These districts are Nadowli-Kaleo, which is an old district split into two; and Nandom, which was previously part of Lawra district. The new districts were digitized from historical maps of the former districts based on reference coordinates obtained from the districts' profile. The district profile is a document prepared by the District Assemblies (DAs), which describes the major biophysical and socioeconomic characteristics of the district. The districts' limits were also indicated on the hardcopy maps by local authorities at the DAs. These maps have been used for quantifying other parameters of the study such as population density and vegetation removal. Polygon shapefiles, accompanied by numerical values of land cover types, have been prepared by the Centre for Remote Sensing and Geographic Information Services (CERSGIS), University of Ghana, covering all the ecological zones of Ghana. Details of the survey methods used in the preparation of the land use/cover data can be found in (Agyapong et al., 1999). The land use/cover data were obtained and used to estimate the potential tree cover displacement by exploration and mining activities in the study area. Polygon shapefiles of ELs were obtained from report 43–101 downloaded from the website of Azumah Resources Limited (2013), digitized and used for socioeconomic, environmental, and potential water-use conflict analysis. Currently, Azumah Resources is the only company holding mining leases, together with 27 out of the total 28 ELs granted in the study area.

2.3. Data analysis

2.3.1. Ground water stress index (GWSI)

Ground water stress index is the ratio of annual groundwater withdrawal to water availability. This study adopted and modified the criticality ratio (CR), also known as the *withdrawal-to-availability ratio* of (Alcamo et al., 2007) to estimate the GWSI. The availability in this sense refers to both surface and groundwater. However, in arid and semi-arid regions the volume of major rivers, such as the Nile and Niger, reduces during the dry season, and most streams, hand-dug wells and artificial dams dry up and are only restored during the rainy season. The Volta Basin in West Africa is an example of this also. Hence, to measure water stress in the Northern Savannas of Ghana, this study considered only groundwater. This is the reliable source of water for communities throughout the year; over 95% of it is used for domestic purposes (Obuobie and Barry, 2010). By definition, CR values range between 0.00 and 1.00. $CR \leq 0.20$ indicates very low stress to no stress at $CR = 0.00$. $CR \geq 0.40$ indicates moderate water stress and above 0.80 indicates water scarcity (Alcamo et al., 2007). The annual withdrawal of water (x) is computed using 50 L as the average per capita water in the area (Martin and Van De Giesen, 2005). The 50 L is multiplied by 365 days in a year and the total rural household population in each district. This is summarised in the following equation:

$$x = 50 \times T \times P_J \tag{1}$$

Where T = 365 days in a year, and P_J = Population in district (J)

Sources of groundwater in the area include wells, boreholes, pipe-borne from treatment plants and public taps. (Martin and Van De Giesen, 2005) estimate the groundwater availability (y) in the Volta Basin to be $88 \times 10^6\,m^3$.

The CR index is therefore a region-wide index. To understand the spatial disparities of water stress at the district level, the Ground Water Stress Impact Index is computed.

2.3.2. Ground water stress impact index (GWSII)

The quality of groundwater also determines its potential availability for populations. A region may have sufficient groundwater but it may not be readily accessible due to insufficient quality. Moreover, health issues related to unsafe drinking water may also be felt in areas that have restricted access to healthcare facilities. Therefore, in this study, poverty and populations have been taken as indicators against which the impact of groundwater stress is measured. In doing this, the water stress index is multiplied by the number of rural household who depend on groundwater for any purpose. This is expressed in the model below:

$$GWSII_J = [GWSI \times (P \times PI)]_J \tag{2}$$

The groundwater stress impact index of a district (J) is the product of its groundwater stress index, rural household population, and poverty index. Crude Death Rate (CDR) is used as the poverty indicator (PI) in this study. The CDR is the number of people who die out of every thousand within a year (GSS, 2013). This was considered to be the best choice of indicator for PI in this study because, generally, records of deaths in rural communities mainly indicate causes due to diseases(WHO, 2010). Most of these diseases are acquired through unsafe drinking water. Hence, a locality's portfolio of access to health facilities may be used to measure its poverty status (WHO, 2010).

2.3.3. Potential mining induced ground water stress (GWS)

Projecting the future effects of a mine during its entire lifespan requires an evidence-based analysis of the ways in which the industry's activities contribute to GWS. To achieve this, the borehole and well data have been overlaid onto the ELs. Much like surface water drainage basins, groundwater (GW) flows from areas of high elevation to low elevation. Therefore, the stream network in the study area was used to illustrate the possible flow direction of GW and potential intersections with mine leakages downstream. However, a study of the mine operations plan in the area did not reveal an explicit proposal for GW abstraction in their concessions. Instead, plans for surface water usage were expressed.

2.3.4. Surface water stress index (SWSI)/impact index

Surface water stress index is the ratio of mean annual precipitation (PANN) to potential evapotranspiration (PET). Rather than using the CR model to compute the SWSI, the Aridity Index (AI) has been used as a proxy for the SWSI. The AI is the most suitable index for the study area since most surface water bodies are strongly seasonal. The AI is computed using the PET value for the Guinea Savannah regions in Ghana, which has been determined to be 1652 mm (EPA, 2003). The mean monthly rainfall data are used to compute the PANN values for all rainfall stations in the districts. The AI for the entire UWR is then calculated. Surface Water (SW) bodies included in this study are: unprotected wells, springs, dams, dug-outs, ponds, rivers, and streams. Values of the AI range from 0 to 1, representing desert to no-aridity lands (UNEP and Thomas, 1992).

A 0.54 value is usually quoted as the AI for the Guinea Savannah regions (EPA, 2003). However, this value cannot be applied in this study, since precipitation values vary spatially and temporally across the region. Therefore, locally-derived AI values were converted to a Triangulated Irregular Network (TIN) in ArcGIS. The TIN was then used to create a raster map with a minimum value of 0.4 and a maximum value of 0.74. These values were then used to develop an iso-aridity map, delineating the entire UWR into different levels of aridity classes. This shows the areas with potentially available SW and spatial variation of aridity in the study area. Finally, the PIs of all the districts were used together with the AI and rural household populations to compute the Surface Water Stress Impact Index (SWSII). This reflects the potential impacts of surface water withdrawals on populations. Due to lack of models in the literature for computing a SWSII, the model in Eq. (3) was developed:

$$SWII_J = [1 - AI \times (P \times PI)]_J \tag{3}$$

The aridity index is subtracted from 1 and the result is multiplied by the population and poverty index of each district.

2.3.5. Potential mining induced surface water stress (SWS)

The major ways in which mining industry activities can induce SWS include withdrawal, pollution and sedimentation of dams, stream and rivers. In an example of the latter effect, Zhao et al. (2013) found that the displacement of vegetal cover near the Loess Plateau resulted in erosion and flood hazards, leading to SWS. Grasses and tree cover are necessary for lowering soil erosion risks, and once removed, expose an area to water and sediment runoff. Soil erosion by water is pervasive and contributes to stream, river bed and dam sedimentation in the Northern Savanna regions of Ghana (World Bank, 2006). Therefore, this study quantifies the amount of vegetation potentially displaced under each EL using the land use/cover data and the number of trees per land cover type in each EL. The model below was developed for this analysis:

$$AvNT_{J\_}-S = (EstNT_{yELJ}) \tag{4}$$

(-S) = displacement
AvNT = Average number of trees;
EstNT = estimated number of trees;
y = land cover type; J = district

The number of trees potentially displaced in each location was calculated as the sum of the estimated number of trees per land cover type per EL in a district. This is done by clipping the land cover maps to the EL data. The estimated number of trees was calculated by multiplying the average tree density in each land cover type by the amount of land cover area overlapping with an EL in a district. For instance, the open cultivated Savanna Woodland has 11–20 trees/ha. Hence, the average tree density for open cultivated Savanna Woodland would be 15.5 tree/ha. The following expression was developed to estimate the amount of grasses and herbs potentially displaced by mining industry activities:

$$F_{J\_}-S = (\sum F_{ELJ}) \tag{5}$$

F = Forage

Given that forage (F) per hectare in a year in the Northern Savannah is 2170 kg (Oppong-Anane, 2006); the amount of grasses and herbs potentially displaced was calculated by multiplying the amount of forage per hectare by the area of an EL ($F_{ELJ} = 2170\ kg \times A_{EL}$) in a district. The results are then summed in each district.

To visualise and measure the potential impacts and spatial extents of surface water pollution in the area, a stream network analysis was performed. Using a Filled GDEM, the flow direction of stream networks was computed and then a flow accumulation network was developed in ArcMap. The flow accumulation had a minimum pixel value of 0 and a maximum of 2.15. However, the mass of lower order streams in the flow accumulation network was too dense. These lower order streams included some that probably developed out of erosional effects and had minimal contribution to flow. Therefore, a conditional tool was imposed on the flow accumulation stream network to trim out less-important streams. Horton's law of stream order was also applied to order the stream network, to allow satisfactory visualisation of the drainage network in the study area. A drainage basin was then developed using the flow direction network, and the ELs were then overlaid onto the drainage network and basin data. Although the stable volume of water in the Black Volta is unknown, the exploration/mining company plans to withdraw up to 7000 m^3 of water per annum from the Black Volta for its operations (Azumah Resources Limited, 2013). This may have latent implications on communities.

The population data were used to calculate the density for each district (Fig. 4). This was done in order to understand the current status of water demand, and also to test the hypothesis that impacts of water stress are intense in densely populated areas (UN-Water, 2007).

2.3.6. Potential conflicts hot-spots

To assess the more likely areas for potential conflicts triggered by MIWS, the boreholes, wells, dams, ponds and dug-out points, as well as the drainage network data were overlaid onto the ELs. This

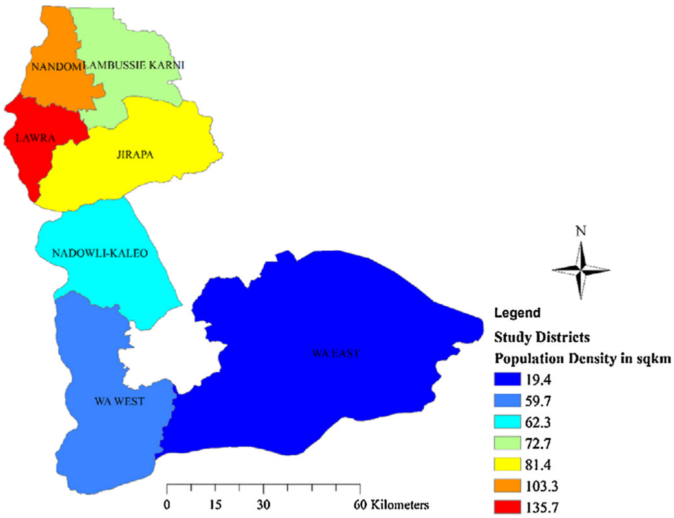

Fig. 4. Population density in the study area.

allowed for a visual inspection of the spatial extents and potential interactions of the ELs with sources of water for local communities. The primary focus was on the two districts with current mining concessions: Nadowli-Kaleo, and Wa East. The Community Development Toolkit of the International Council on Mining and Metals (ICMM) gives a threshold distance of 20 km for assessing the impacts of mining-associated activities on nearby communities (Mining and Metals, 2008). Thus, Akabzaa et al. (2007); Aragon and Rud (2015) found attenuating results beyond this threshold, for the contamination of water resources by the mining industry's activities in the gold mining districts of Ghana. However, Lin et al. (2005) also found that the impacts of acid mine drainage (AMD) on surface water pollution only reduced beyond 26 km from the source. Hence, a 26 km buffer was adopted around the mine operation area in both concessions to represent potential long term water stress and cumulative impact areas. In addition, a 20 km buffer was also created to capture areas potentially more directly affected. Major villages within the buffers' distances were sampled during fieldworks, using a stratified random sampling technique. These have been represented by point shapefiles in the analysis. Although the buffers transcend the boundaries of Ghana, communities could not be sampled from outside of the country due to cross-border protocol issues.

3. Results and discussion

Fig. 5 shows the GWSI across the study area. The highest index recorded for the study area was 0.016. This value corresponds to demand for GW for drinking purposes in the Wa West district. The lowest index was 0.008, which shows water demand for other usages such as washing and gardening. These results are an indication of existing water stress levels in the area prior to mining industry activities. With reference to the Alcamo et al. (2007) index thresholds, the entire study area can be considered to have low GWS.

However, the current values of the GWSI may be altered by contamination and over-abstraction of aquifers used for mining (Fig. 6). The stream network in Fig. 6 shows that GW is likely to flow from the direction of the settlements towards the mine site, along the course of the streams. Aquifer flow is likely to be interrupted and the amount of discharge and supply levels at the boreholes, wells and GW treatment plants may be affected. Therefore, groundwater pollution may be expected to have a minimal effect on those settlements; this agrees with the findings of Akabzaa et al. (2007) in the Obuasi mining district of Ghana. However, contamination of the hydrological pathway upstream can have an extensive effect on the downstream users within the same watershed. Thus, samples of potentially affected villages have been included via the 26 km buffer zone, although there are currently no plans for GW abstraction for mining activities in those downstream areas. Thus, as Peters and Meybeck (2000) suggest, excavation of land beyond the depth of water Table can affect water balance and its quality. Whereas surface mining pit depths can exceed 100 m, Carrier et al. (2008) found that the water Table level of the UWR is generally between 20 and 25 m in depth.

The Jirapa district recorded the highest GWSII; followed by Nadowli-Kaleo, and then Wa West with indices of 12, 9.9, and 11 respectively for rural household drinking water; and 10.5, 9.6, and 9.4 respectively for rural households for other uses (Fig. 7). Nandom and Lambussie Karni districts are the least-affected areas in terms of GWSII for all water uses. The overall study area did in fact contain localised areas of water stress, as indicated by Fig. 6. There are remote villages and hamlets that do not have access to potable water for domestic chores. Some of these remote

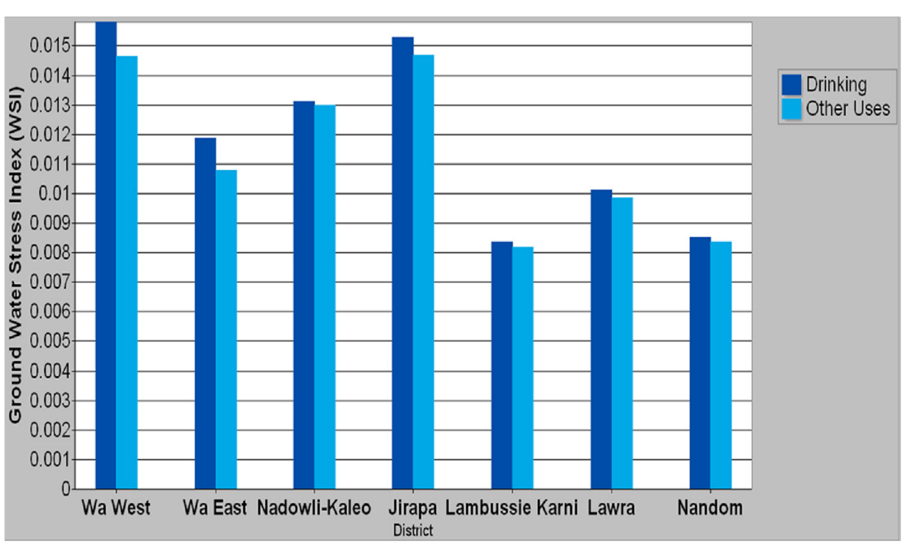

Fig. 5. Ground water stress index (GWSI) in the study area.

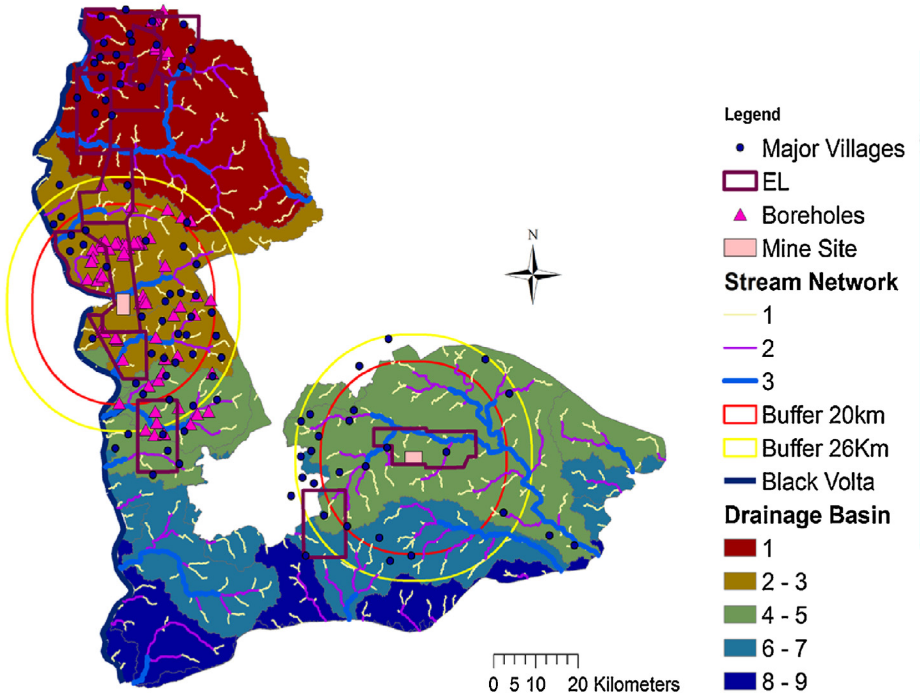

Fig. 6. Potential Mining Induced Ground Water Stress (MIGWS).

settlements were identified during fieldwork, particularly in the Nadowli-Kaleo, Wa West, and Jirapa districts. The low water stress areas arising in Fig. 7 account for such remote settlements within the study area, which depend on low yielding wells for water. Any mining-induced immigration would increase population and economic activity in these districts, resulting in an increased demand for water. This possibility may devolve the current water stress status to scarcity levels; holding climate, geology and infrastructure constant in the districts. On this basis, it can be predicted that, with the introduction of mining industry activities, districts shown to have lowest GWSII may experience the highest magnitude of impacts as well as those with low yielding ground water sources. This was also anecdotally observed during fieldwork and reflects the apparent reality on the ground.

Fig. 8 shows the aridity indices (AI) of the study area. The Wa-Lawra belt and the east of Jirapa district have AI values ranging between 0.40 and 0.52. The rest of the UWR has an AI between 0.66 and 0.73 (Fig. 8). These indices were used as the SWSI. With reference to the United Nations Environmental Programme (UNEP) (UNEP and Thomas, 1992) classification of AI, the Wa-Lawra belt (that is, the North-western portions of the study area, including areas around east of Jirapa district), would be considered as more vulnerable to arid conditions than the east of the study area. The rest of the study area can be classified as semi-arid. The indices therefore indicate that the generally cited AI of 0.54 or 0.64 for the UWR (EPA, 2003) does not apply in detail to any of its constituent local regions. The spatial distribution of SWS potentials is visualised in the iso-aridity map (Fig. 8). This map shows a more micro-level detail of aridity status and the likely shortages of SW for any type of use in the UWR. This level of detail is recommended by the (UN-Water, 2007). The iso-aridity map also compares well with the desertification hazard prone map of the UWR in its spatial arrangement, particularly for the Lawra-Nandom belt (EPA, 2003). In general, the results show that there are marked variations of SW

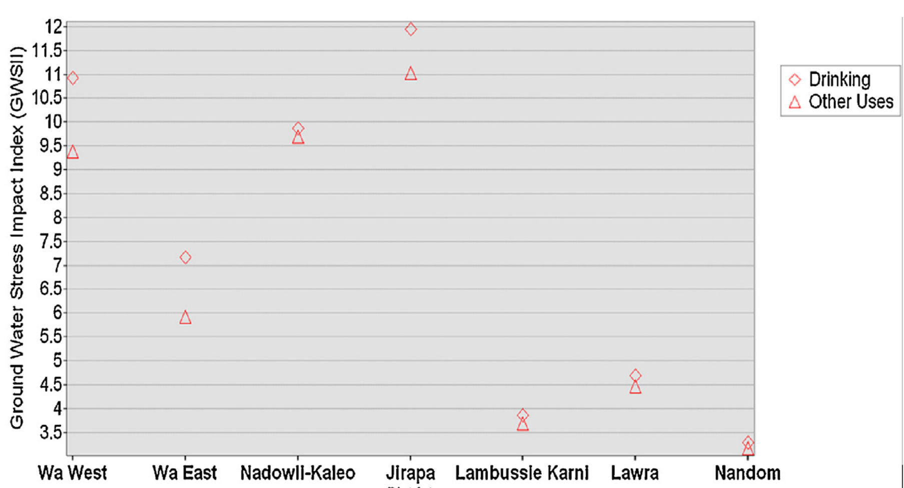

Fig. 7. Ground water stress impact index (GWSII).

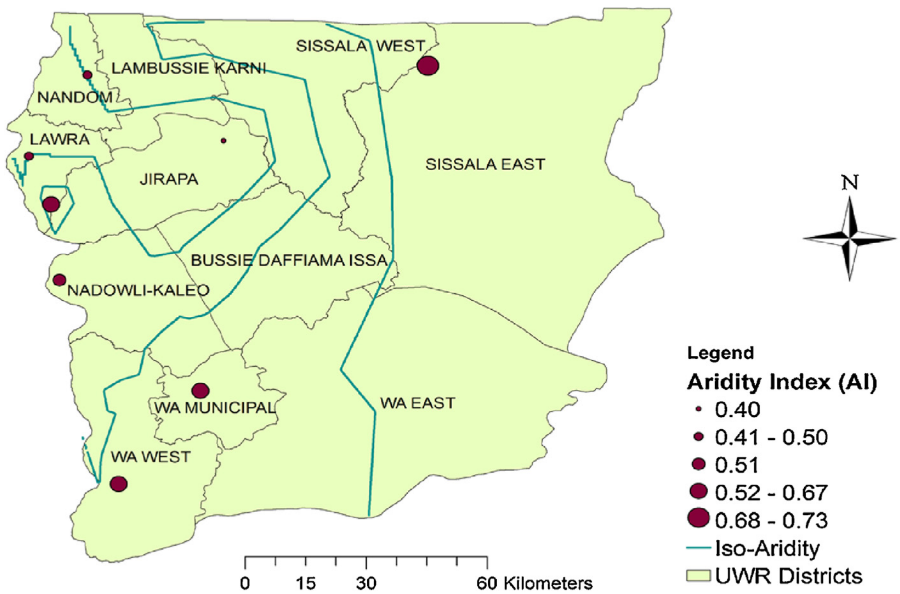

Fig. 8. Iso-aridity map of the study area.

availability for rural communities in the region. Wa East district would appear to have copious SW in dams and ponds, as well as the Wa West district. This is, however, reminiscent of the data shown on Fig. 4, where the index cannot account for the fact that both Wa East and Wa West have more rural households depending on SW for both drinking and other domestic purposes.

Fig. 9 shows the results for the Surface Water Stress Impact Indices (SWSII). Wa East district had the highest SWSII of 229 and Nandom district had the lowest of 8 rural homes in terms of their dependency on SW as a source for drinking purposes. Wa East also had the highest SWSII of 78 households, closely followed by Jirapa district with 74 rural households in terms of their dependency on SW for other domestic activities. Nadowli-Kaleo, and Nandom districts had the lowest of 8 and 10 homes respectively. Overall, Wa East district has the highest dependency on SW for drinking purposes. Hence, any potential SW contamination may be expected to affect large numbers of communities in the area.

Fig. 10 shows the areas of potential vegetation removal and consequent top soil erosion, potentially leading to surface water siltation. Nandom district has the highest potential vegetal displacement of 38,959 trees and 713,404 kg of grasses and herbs due to large areas of ELs in that district. Wa West district has the lowest vegetal removal of 2432 trees and 229,020 kg of grasses and herbs, relative to the land cover type and area of ELs. Nadowli-Kaleo and Wa East districts have moderate vegetal displacement, although Wa East has the second highest grasses and herbs displacement of 641,655 kg. The combination of potential tree and grass displacement exposes surface water bodies to siltation via eroded sediment loads and weed infestation. Both the Black Volta and Kulkpong rivers are most vulnerable to this phenomenon due to proximity to mine sites.

Furthermore, it is evident from Fig. 11 that mine site operations could interfere with both first order and higher order streams. It may be observed that most dams and ponds source their water

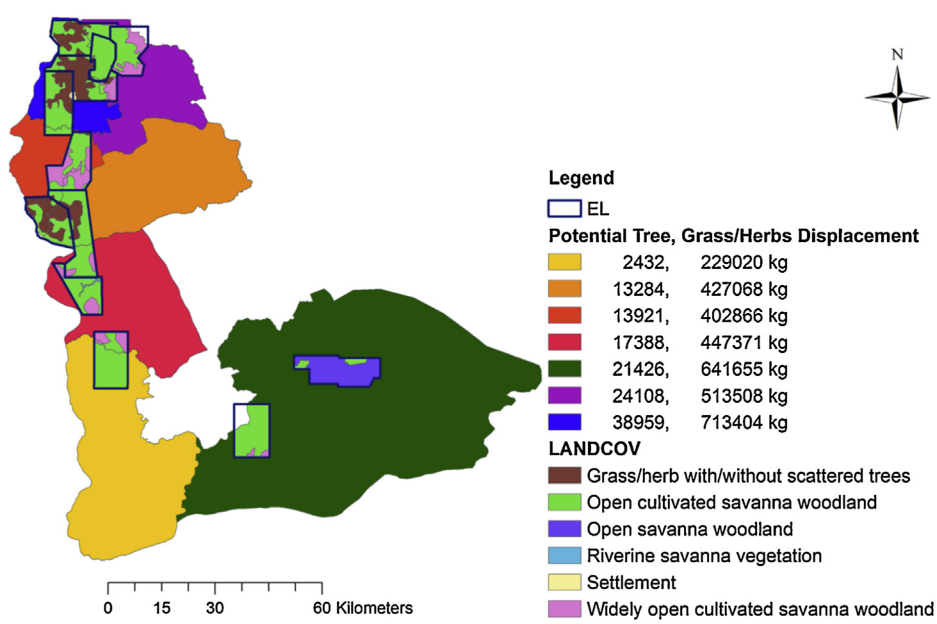

Fig. 9. potential vegetal removal due to mining concessions.

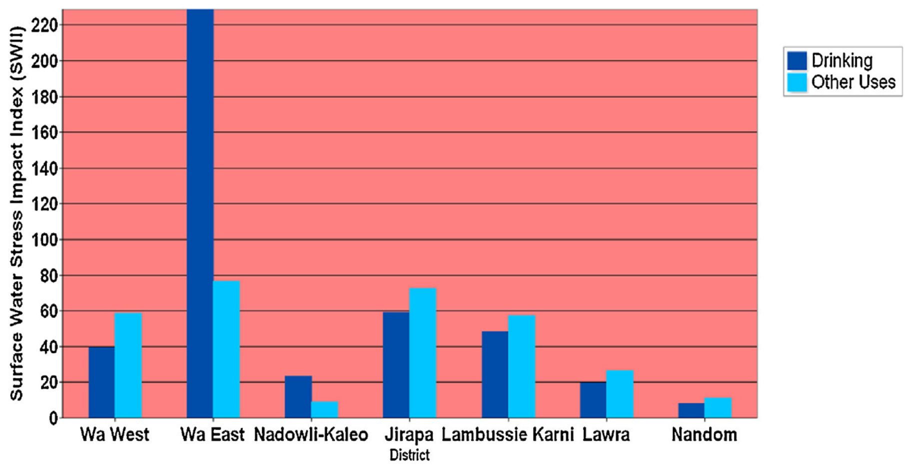

Fig. 10. Surface water stress impact index (SWSII).

from adjoining streams. Some streams also originate from dam and pond spillway banks. Consequently, the linkage between streams and destination dams that serve the domestic water requirements to local communities has the potential to be interrupted. Lin et al. (2005) found that chemical pollution of surface water bodies started from a first order stream channel down to receiving points. In this regard, local communities' resistance to mine operations near first order streams and dams may be anticipated. In Nadowli-Kaleo district, the 26 km buffer covers many villages near first order streams. However, the 26 km buffer does not cover many villages in Wa East, nor does it transcend the boundaries of the UWR. By extending the potential area of influence, major local communities potentially affected in the longer term include: Funsie, Tuosa, Tisa, Loggu, Olemuni, Gbantala, Mangwe, Katuo, Kpagloghi, Tabiase, and Cheringu in the Wa East district; Dabo, Oli, Bulituo, and Eggu in the Wa West district, Charibile, Guonor, Gbanko, Banungoma, Sankana, Takpo, Jumo, and Sombo in the Nadowli-Kaleo district; Lawra, Domweni, Baseble, and Gengenkpe, in the Lawra district; and Jirapa, and Tizza, in the Jirapa district. Localities that are also within any EL fall within this category even though they may not intersect with a buffer.

Importantly, there is also the possibility of pollution of the Bakpong and, subsequently, Black Volta rivers. The Bakpong River flows directly into the Black Volta (Fig. 11). Meanwhile, the Black Volta is a shared river in the frontiers of Ghana, Burkina Faso in the North-west and Ivory Coast in the South-west of UWR. As a result, mine site contaminants from the Bakpong River into the Black Volta may potentially create inter-state conflicts between the Republic of Ghana and her neighbours along that watercourse. The UN-Water (2015) reports that 158 of the world's 263 transboundary water basins lack cooperative mechanisms for managing shared water resources between neighbouring countries. Details of recent disputes resulting from policy gaps and transboundary resource extraction, especially between Ghana and Ivory Coast, can be found in (Adusei, 2015) and (Bening, 2015). Hence, the potential for continued conflict due to future mining activities is apparent.

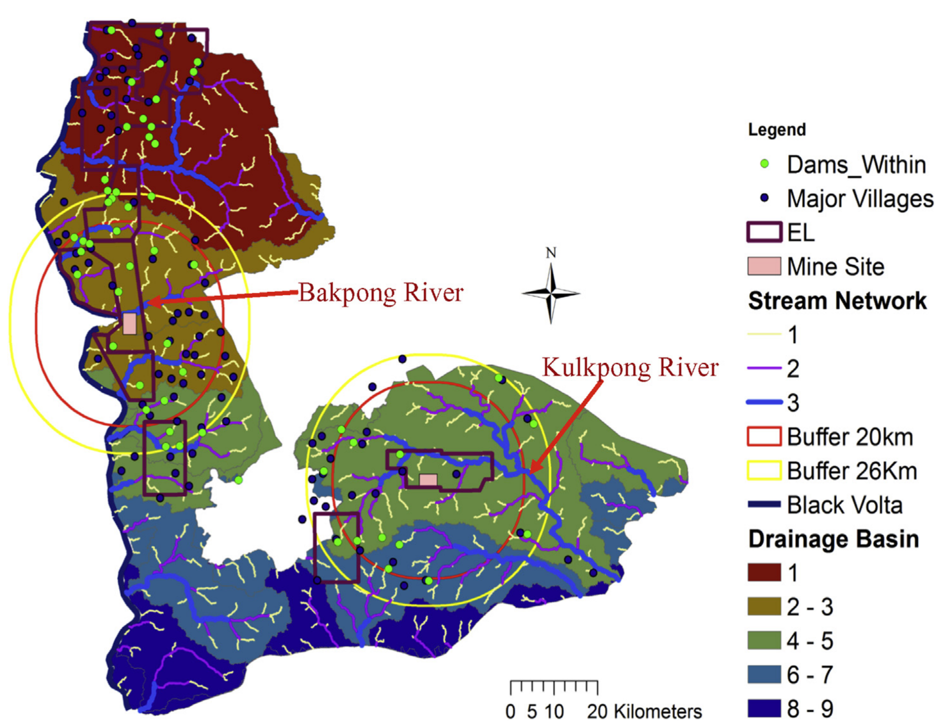

Fig. 11. Affected areas along 20 or 26 km buffer zones.

Potential conflict hot-spots were identified within the 20 km buffers (Fig. 11). Fig. 11 shows that, in the Wa East district, most of the contributing streams to the Kulkpong river originate from within the 20 km buffer. Thus, future mine expansions have the potential to capture more streams and potentially increase the sediment loads of dams and adjoining streams. Villages identified in the hot-spot areas include: Nanga, Tangasia, Yiziri, Musama, Banu, Nator, Goli, Nadowli and Cherekpong in the Nadowli-Kaleo district; Yagha, Orifane, Kpannyaga, Guoripuo, and Kul-Ora in the Jirapa district; Birifo, Babili, Gbare, Kunyukuong and Koro in the Lawra district; and Donfia, Donyuokuraa, Viisey, Baayiri, Goripie, and Bulenga in the Wa East district. Village settlements adjacent to the Black Volta in Burkina Faso are also part of the potential conflict hop-spot areas. Moreover, the Bakpong mine site in the Nadowli-Kaleo district has the potential to block or divert the course of the Bakpong River into Orifane, a nearby village to the north (Fig. 11). This is a double-edged potential impact; i.e. water pollution or over-abstraction, and flooding from the diverted or stemmed river course. Nanga, Tangasia, and Yiziri also directly share frontiers with the Nadowli-Kaleo mine sites. Therefore, these villages would be the first to encounter the effects of mine site water contaminants and GW over-abstraction. The exploration/mining company's plans to withdraw water from the Black Volta have already ignited a growing public debate. The arguments revolve around the GWSCL confirmed advanced plans to supply potable water from the same source, coupled with reducing water capacity. Therefore, the findings of this study should be shared among stakeholders for informed decision-making, and meaningful negotiations.

4. Conclusion

This study investigated the spatial distribution of water sources and demand in order that mining industry activities might be planned to mitigate water stress and associated conflicts in the emerging north-west gold province of Ghana. Shared information about the spatial interactions and relationships between the mining industry activities, water sources, shared water resources, water use/stress and conflicts in resource-rich developing countries is rudimentary (Budds and Hinojosa-Valencia, 2012). The study modified the criticality ratio and aridity index models to measure ground and surface water stress indices in the area. An Aridity Index (AI) ranging between 0.40 and 0.52 in the Wa-Lawra belt and the east of Jirapa district are indications that this area is vulnerable to water stress impacts. The introduction of mining sector activities could lead to increases in water use and demand. This comes with latent impacts of MIWS on communities through over-abstraction of groundwater, pollution, surface water sedimentation, or diversion of stream channels. The calculated GWSII and SWSII of a maximum of 12 and minimum of 9.4 rural homes may warrant urgent concern in future mine site planning and negotiations. However, it is observed in this study that Nandom and Lawra districts, with higher population densities, of between 103 and 135 persons per square kilometre, are less vulnerable to impacts than areas with low densities.

Overall, this study provides baseline knowledge that may enhance informed decision-making, efficient mineral resource development, and water resource management. The results may enable knowledge sharing between local communities, companies, governments and civil society groups, concerned with the spatial extents of projects approvals and environmental degradation (Bebbington and Williams, 2008). Furthermore, the results of this study can be used as benchmark indicators for monitoring and evaluation, validating the EISs and SIAs of companies in the study area (World Bank, 2006). Most importantly, the findings may be used for evidence-based establishment of mechanisms for an efficient management of shared water resources between neighbouring governments along the Volta basin in West Africa. This is in line with the post-2015 development agenda of the African Union (Union, 2014).

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CHAPTER 8 Landscape Assessment for Sustainable Resettlement of Potentially Displaced Communities in Ghana's Emerging Northwest Gold Province

This chapter is covered by the following manuscript, which is still under peer-review as the time this thesis was submitted:

Moomen A-W, Dewan A, Corner R, Landscape assessment for sustainable resettlement of potentially displaced communities in Ghana's emerging Northwest Gold Province, *Journal of Cleaner Production* (2016), doi: 10.1016/j.jclepro.2016.06.004.

Chapter 8 provides a non-weighted, non-standardised spatial suitability analysis for considerations of sustainable livelihood, in the event of mining sector-led displacement. It assesses holistic environmental circumstances under which displaced communities might find improved livelihood after the introduction of the mining industry activities in the local landscape. These include permitting landscape conditions for both agricultural and non-agricultural rural livelihoods. The analysis envisages the possibilities of establishing forward and backward linkages between the mining industry and local production systems. That is, finding possibilities of peaceful co-existence between the mining sector, agriculture, and other land use interests in the local landscape.

Even though the chapter may suggest that resettlement is not a sustainable option, it still requires all stakeholders to sit together, plan and take important decisions with the aid of facts on the ground (local realities) as provided in this study. In resource conflict management, these findings form strong basis for mediatory processes and to avoid impoverishing already vulnerable communities. Thus, communities' land use activities would definitely be displaced by exploration and mining activities. This has already been the case; during fieldwork many communities reported they are already getting frustrated with the level of exploration activities going on their farmlands.

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Landscape assessment for sustainable resettlement of potentially displaced communities in Ghana's emerging northwest gold province

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A B S T R A C T

This study assesses the physical suitability of the local landscape to enhance resettlement of future displaced communities as a result of mining. The study focuses on Ghana's emerging northwest gold province. Landsat images from 1986 to 2014 were used to map land-use/land-cover changes to predict future changes. Participatory mapping and focus group discussions were incorporated, to develop reference points, training sites and land use areas by villages. The results showed that expansion of occupied lands occurred from 25.4% in 1986 to 44.8% in 2014 with associated increasing population densities. Predicted land-use/land-cover changes indicated 52% expansion of occupied lands over a 15 year period. Much of that expansion was from vegetation and waterlogging. The results also showed large patterns of waterlogging in the area. The existing and predicted landscape character in the area indicated unsuitable environments for enhanced resettlement and livelihood to potentially displaced communities as a result of future mining operations.

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1. Introduction

Globally, mining-induced displacement and resettlement of local communities is a common phenomenon. Nonetheless, identifying suitable landscapes, before a project concept, for optimal relocation of potentially displaced communities has been a governance aberration in developing countries. Meanwhile, policy transformations and technological advancements have expanded the frontiers of mineral resource exploration and extraction into previously inaccessible areas in these countries (Hilson, 2004; Thomson and Joyce, 1997). Besides, the United Nations Economic Commission for Africa, the World Bank and African Union (AU) recognition of the mineral resources sector as a panacea to economic growth and industrialisation (Africa, 2009), has engendered a proliferation of mining sector investments in Africa. For instance, there was a minimum of 230 Australian exploration and mining companies in Africa in 2011, pursuing about 650 projects in 42 countries, including Ghana (Catherine and Andrew, 2012). Thus, large tracts of rural space are often leased for open-pit mining, thereby, invoking displacement, resettlement and sustainable development concerns of local communities. Sustainable development refers to the use of environmental resources in producing the present needs of society in ways that do not compromise the ability of future generations to meet their own needs from the same resource base (Bruntland, 1987). Resettlement is the physical relocation of settlements or livelihood activities from their present area of occupancy to new locations (Cernea, 1997).

Since the publication of the Brundtland report (Bruntland, 1987), Convention 169 (International Labour Organisation, 2013) and the Agenda 21 (UNCED, 1992), the attention of scientists, policy makers and the mining industry has been drawn towards placing rural communities at the centre of land use planning and resource creation. The Brundtland report emphasises two key concepts: prioritising 'needs' of the local communities and protection of the natural environment's ability to meet present and future needs of local communities. These needs include food security and economic livelihood. Thus, sustainable resettlement refers to a recognition of the potentials and risks of landscapes that would support the diversity of enduring livelihood activities of displaced rural communities in mining regions (Cernea, 2003; Downing, 2002). Nonetheless, Downing (2002), Owen and Kemp (2015) found that mining leads to resettlement of displaced communities on low productive and agriculturally unsuitable areas, leading to impoverishment and conflicts. For example, Schueler et al. (2011) found

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that mining-induced displacement and resettlement of farming communities on unsuitable agricultural lands, in south-western Ghana, resulted in agricultural extensification. This incident led to loss of over 58% forest cover between 1986 and 2002. Similarly, Lillywhite et al. (2015) found that mining-induced displacement resulted in the resettlement of over 736 farming households in Benga, Mozambique, leading to poor water supply, food security issues and flooding hazards.

Governments and companies often introduce financial compensation and alternative livelihoods as mechanisms for mitigating a community's penury after resettlement. However, the scope of these schemes is widely contested in many mining areas. For instance, in the West Kutai area in Indonesia, villagers were paid compensations for resettlement. Notwithstanding, the local communities resisted relocating on the basis of a longer-term view of the compensation packages (Jenkins, 2004). Likewise, in the Tarkwa mining district in Ghana, it is reported that displaced communities complained of unfavourable compensation arrangements that led to livelihood disarticulations (Taabazuing et al., 2012). Women traders in resettled communities were displaced out of business due to a disconnect with customers in their new settlements. In this regard, De Wet (2004) and Hilson and Banchirigah (2009) postulate that communities' resistance against the mining sector is due to the unsustainability of resettlement schemes and lack of prior resettlement surveys (Downing, 2002). Thus, it gives a new recognition of the probes of Cernea (2003): ‘The question not asked: when does displacement end?’ Hence, Moran and Kunz (2014) suggested a delineation between Sustainable Development (the longer-term socioeconomic benefits of the mining industry to communities) and Operating Sustainably (best environmental stewardship of the sector).

The mining industry has introduced various initiatives to address sustainability issues in its operations. These include the Mining, Minerals and Sustainable Development (MMSD) project. On this note, the International Council on Mining and Metals (2008) introduced the community development toolkit, which undertakes baseline studies and Social Impact Assessments of affected communities. Measures such as buffer zones and offsetting would be introduced to mitigate the potential negative effects of future mine expansions (Sonter et al., 2014a). These tools are a means of identifying and measuring the potential impacts of projects on local communities (Catherine and Andrew, 2012). The World Bank, on its part as a major financier, also instituted the Resettlement Action Plan (RAP) and the Equator Principles (EP). These directives are expected to be implemented by governments and companies, to ensure sustainable mine operations as well as sustainable resettlement of displaced communities. The RAP and EP guidelines provide that the operations of mines on local space should not stifle the ability of displaced communities and individuals to find more improved livelihood than their pre-displacement conditions (Downing, 2002; Principles, 2013). To this end, remote sensing and geographic information systems (GIS) tools have been widely used to assess the effects of surface mine expansions and reclaimed lands on resettled or neighbouring local communities. Examples include (Craynon et al., 2015; Schueler et al., 2011; Sonter et al., 2015; Townsend et al., 2009).

Nonetheless, the community development toolkit, resettlement action plans and equator principles do not establish explicit criteria, such as buffering parameters, to secure a sustainable livelihood for resettling rural communities. While feasibility studies of a mine are usually done ahead of operations, feasibilities of sustainable livelihood of potentially displaced communities come after mine commissioning (Owen and Kemp, 2015). Earlier studies have given insights into the unsuitability of resettlement schemes for the livelihood of displaced communities. However, there are limited studies providing rural landscape analysis for enhancing resettlement planning decisions of potentially displaced communities, particularly, in Africa. Besides, few studies have established benchmarks, linking the influence of communities on land-cover dynamics and the potential effects of future mining activities on existing land-use/land-cover patterns (Sonter et al., 2014a,b). Also, there is a paucity of land-use/land-cover information for rural resource management in the Northern Savannah regions of Ghana. As such, large-scale mining is an emerging land-use activity in the area. Hence, anticipated transformations on existing land-use and livelihood activities due to the mining sector activities, are not yet understood in context.

Therefore, the main objective of this study is to assess the physical suitability of local space to enhance options for sustainable resettlement of potentially displaced communities as a result of mining. Thus, this study: (1) characterises current land-use/land-cover patterns to establish baseline conditions of the landscape prior to mining; (2) identifies the spatial extents of concessions and their interfaces with local communities to determine potential displacements related to mining; and (3) analyses the development patterns, opportunities and limitations associated with the landscape to place resettlement opportunities and issues in a local and regional perspective. The study is novel in its approach to linking the risks and opportunities of future mining activities with existing landscape conditions. The study is expected to guide spatial planning and potential land use conflicts management in the emerging north-west Gold province of Ghana.

2. Methods

2.1. Study area

Globally, Ghana is reckoned as a valuable mineral resource country (Standing and Hilson, 2013). The country has significant deposits of gold, diamond, bauxite and limestone, as well as recent discoveries of copper and uranium in the Northern areas (Coakley, 1996; Griffis and Agezo, 2000). However, the gold mining subsector is the largest mineral resource development in the country. Geologically, gold occurrences in Ghana are confined to the Birrimian rocks that underlay the central and south–western portions of the country. Thus, the south-west and central regions of Ghana host the historical gold mining activities in the country. However, the Birrimian rocks further extend from the south-west through the middle transition belt to the three Northern Savannah regions of Ghana. These regions are the Northern, Upper East and Upper West. Hence, geological endowments coupled with industrial advancements have unveiled the value of gold deposits for extraction in the Northern Savannah, particularly in the Upper West Region.

The study focuses on seven of the 11 districts in the Upper West Region, situated between latitudes 9°45′ and 11° 00′ and longitudes 1°30′ and 2°50′ (Fig. 1). The districts are: Wa West, Wa East, Nadowli-Kaleo, Jirapa, Lambussie Karni, Lawra and Nandom. These districts currently have mineral exploration leases and gold mining concessions. The area is covered by the Guinea Savannah agro-ecological zone with scattered trees and grasses. It is a semi-arid region with mean annual precipitation of 989 mm (Blench, 2006). Minimum and maximum temperatures range between 21° and 39 °C (EPA, 2003). The upper west region had a total population of 702,546 in the last population and housing census (GSS, 2013). Most of the region's population is concentrated along the Wa-Lawra belt in the western corridor (Fig. 1). The region is also the second poorest in the country with a per capita income of less than US$ 1 (GSS, 2007). Agriculture is the primary economic activity in the region, employing about 80% of the population and over 90% of rural households (GSS, 2013; RADU, 2010). However, it is

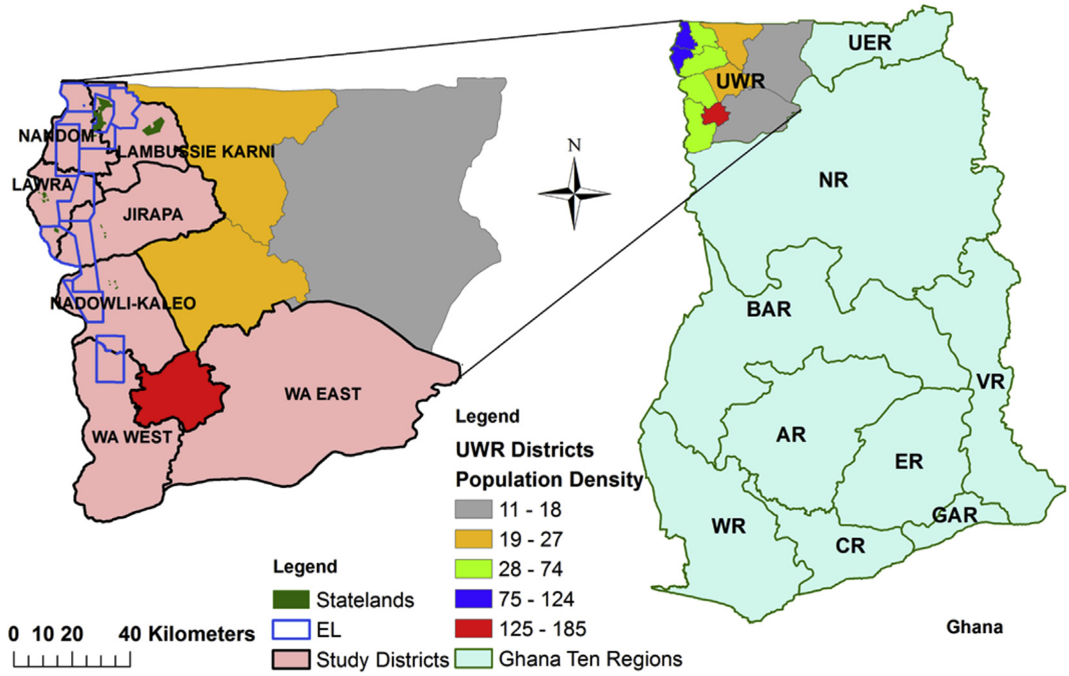

Fig. 1. Location of the study area.

hypothesised that the type of farming systems practiced in the Northern Savannahs of Ghana account for poverty prevalence in the area (Al-Hassan and Poulton, 2009). Nonetheless, DFID (2005) suggests that agriculture holds the key to economic development of the Northern Savannah. However, the agriculture sector growth requires high capital that can be obtained through the development of its mineral resource endowment (DFID, 2005).

2.2. Data preparation and analysis

2.2.1. Rural appraisal

A field visit was conducted in the study area between November 2014 and February 2015. During fieldwork, the consent and support of local authorities at the district assemblies were sought. The district assembly is the local governance system in Ghana, which represents local communities and grassroots participation on developmental and policy interests. It comprises of elected representatives (assemblymen) of localities. A multi-stage sampling protocol was employed in this study to identify the study communities during the fieldwork. With the aid of a mining concessions map of the area, the assemblies, through the assemblymen, further helped to identify and access villages that are enclosed by the concessions. Communities were then sampled based on clusters of kinship ties and proximity regarding land use patterns. Three focus group discussions and mapping activities were held in each community. During focus group discussions, community groups were identified, and a representative from each cluster was requested to participate in the data collection activities. Community groups identified included youth associations, women associations, chiefs, traditional priests, experienced farmers and hunters.

To determine the potential physical/economic displacement of local communities and the need for resettlement, the extents of local communities' land use space was developed through participatory mapping and resource inventory activities. Each mapping and focus group discussion involved a minimum of 10 participants. In total, about 530 community members took part in the focus group discussions and mapping. During the map sketching, community representatives identified and described the relative positions of the community's valuable sites including farmlands, dams/ponds, boreholes, dwellings, sacred groves and cemeteries. The sites were georeferenced during field transect walks, using a handheld GPS with a 5-m positional accuracy. The communities surveyed can be found in the supplementary sheet attached. Timelines were also drawn to identify historical sites and land-use/land-cover features of communities on satellite imagery. During transect walks, sites of some extinct land-use/land-cover features described on the timelines were georeferenced with a handheld GPS, photographed and used to aid training polygons for the 1986 and 2000 images.

Coordinates of last farmlands of each community were used to register the sketched maps onto ArcGIS for digitizing the land use extents of the community (Fig. 2). It was discussed extensively with community members, during fieldwork, that the digitized land-use/occupancy maps would not represent community maps since the maps are not drawn to show the de facto boundaries of communities. The maps are to be used for understanding the geographies of land-use/land-cover patterns in each community so as to assess a community's spatial interactions with mining interests. Note that Kokoligu was sampled in the Nandom district, but the community could not be accessed for mapping. Hence, only satellite image training data were sampled during the community entry process. Due to resource constraints, communities in the Wa East District were also not sampled. However, training data of land-use/land-cover types were taken from some villages for calibrating satellite data and supporting image classification.

2.2.2. Land-use/land-cover classification

Multi-date Landsat satellite images covering the study area have been obtained from the United States Geological Survey (USGS). Specifically, the images are Landsat5 thematic mapper (Landsat5 TM); Landsat7 enhanced thematic mapper (Landsat7 ETM) and Landsat8 Operational Land Imager-Thermal Infrared Sensor (Landsat8 OLI-TIRS). One Landsat scene covers the entire study area. The images were acquired on 20/12/1986; 18/12/2000/; and

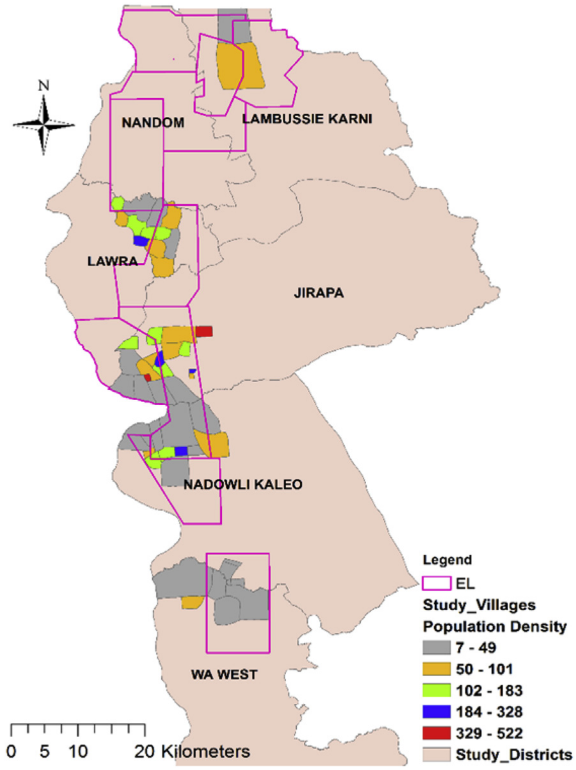

Fig. 2. Location of local communities.

17/12/2014, respectively. All images have 30 m spectral resolution and are cloud free. Bands 1 to 5, and 7 of each image were used for the purposes of this study. For achieving accurate results from a multi-date image analysis, the images were converted from digital numbers (DNs) to Spectral Radiance (Coppin et al., 2004). The Landsat images are level 1T, processed from source and projected to the Universal Transverse Mercator (UTM) Zone 30N in the 1984 World Geodetic Coordinate System (WGS84), with less than 30 m positional accuracy (Tucker et al., 2004). Hence, the spatial accuracy of the images was found to be suitable for the objectives of this study. A Principal Component Analysis (PCA) was conducted to decorrelate the images for enhanced performance (Lillesand et al., 2014) since high correlation between bands was observed while evaluating image quality. The images were reconstituted into six bands using the first three PCA components and were then clipped to the study area extents.

The Land use/land cover map of Ghana developed by Agyapong et al. (1999) describes the landscape of the UWR as consisting of close and open Savannah woodland. The rest are open cultivated Savannah woodland, grass/herb/with/without scattered trees, widely open cultivated, uncultivated Savannah woodlands, riverine areas, settlements and unclassified/bushfire lands. However, Duadze (2004) revised these land-use/land-cover classes, specifically for the upper west region. In the revised edition, the region consists of farmlands/bare lands/constructed surfaces, closed Savannah woodlands and riparian vegetation. The rest are open Savannah woodland with shrubs and grasses, a mixture of grasses and shrubs with scattered trees, reserved woodland, and water bodies. However, for purposes of the current study, the area was delineated into four land-use/land-cover classes using a supervised classification algorithm in IDRISI. These classes are: Water, Waterlogging, Vegetation, and Occupied lands. Water represents dams, rivers and other surface water bodies. This is important for agricultural and domestic consumption. Waterlogged areas represent wetlands, muddy and swamp areas, and wet soils. These provide signals of mining related environmental hazards. Vegetation represents natural vegetative cover, pastures, tree cover and forest lands. The importance of trees and natural vegetation to local communities in the area are discussed elsewhere (Blench and Dendo, 2004).

The upper west region is characterised by granite outcrops, iron pan boulders and large tracts of land without vegetation cover, especially, areas between Jirapa and Nandom. These rock outcrops and bare lands give similar spectral reflectance patterns with concrete surfaces, and dwellings in village settlements. Also, due to the compound farming systems in rural communities (Adu and Asiamah, 2003; Blench, 2006) and the materials used for constructing dwellings (GSS, 2013), it was challenging for both supervised and unsupervised image classification algorithms to segregate between bare/harvested lands and thatched houses built with mud/bricks/straw. These features bear similar spectral signatures. The effects of these environmental phenomena on the spectral reflectance patterns of satellite images in the area have been discussed in detail by early studies (Duadze, 2004). It was, therefore, appropriate to combine these land cover features together under ‘occupied lands’ for developing a robust thematic map of the area. The reconstituted PCA images of each year were stacked to obtain multi-band composite images using bands 4, 3, and 2. A minimum of 10 and a maximum of 20 training site polygons were digitized on the composite bands. The maximum likelihood classification algorithm was run to produce the multi-temporal thematic maps of the study area. The algorithm was chosen because of its efficiency in discriminating between finer and small rare classes and larger objects (Robertson and King, 2011). A 3×3 majority filter was used to remove the ‘salt and pepper’ of the classified images.

2.2.3. Accuracy assessment

To assess the accuracy of the classified images, 100 pixels were sampled on the reconstituted PCA images using a stratified random sampling technique. These were combined with another set of 100 ground data obtained from the fieldwork, giving a total of 200 pixels. A maximum of 50 pixels per class was sampled to test the accuracy of the thematic maps. The image-based reference sampling was aided with an intuitive knowledge of the area, developed during the field visit. Coordinates of the sites of defunct land-use/land-cover features were used to generate reference samples for the 1986 and 2000 images. A confusion matrix was drawn up and computed to generate the producer's accuracy, user's accuracy, errors of omission and commission (Congalton, 1991). The overall accuracy of each thematic map was computed by dividing the correctly classified diagonal pixels, D, by the total number of sampled pixels N (Congalton, 1991). The Kappa Index was then computed using the following formula adopted from Rosenfield and Fitzpatrick-Lins (1986):

$$\frac{N\sum_{i=1}^{r}(x_{ii}) - \sum_{i=1}^{r}(x_{i+} \times x_{+i})}{N^2\sum_{i=1}^{r}(x_{i+} \times x_{+i})} \tag{1}$$

where r = number of rows in the matrix; X_i = total number of correct cells in a class value in row i and column i; X_{i+} = total for row I; X_{+i} = total for column i; N = total number of cells in the error matrix.

The Kappa index is obtained by multiplying the total number of reference sample pixels by the sum of the correctly classified diagonal pixels. Then the result subtracts the sum of the products of column totals and row totals. The final result is divided by the sum of the product of column and row total multiplied by the square of the correctly classified diagonal pixels. A desirable Kappa index should be greater than 80% (Mather, 2004).

2.2.4. Land use/land cover change analysis

To understand the land-use/land-cover patterns of the area, and how non-mining land use activities modify the landscape, a post-classification map comparison was employed using the Landsat 5 TM, Landsat 7 ETM$^+$, and the Landsat 8 OLI-TIRS classified images. The classified thematic maps for the different dates were composited in a GIS matrix to determine the land-use/land-cover change patterns. The thematic maps were compared between 1986 and 2000, 2000 and 2014, and 1986 and 2014. The corresponding change detection image statistics were computed to generate change transition matrices, the rate of change, and areas in hectares. The rate of change, S, was calculated using the following equation:

$$S = \frac{U_2 - V_1}{V_1} \times 100 \tag{2}$$

where U_2 is the area of land-use/land-cover at final time; V_1 is area of land use/land cover at initial time; and $U_2 - V_1$ = change.

The rate of change is computed by first calculating the amount of change. That is, the area of the land-use/land-cover in the final year under consideration minus the area of the initial year. Then, the result is divided by the area of the initial year and multiplied by 100. The registered land-use/land-cover features sketched in the communities were then overlaid with the 2014 classified image to demonstrate the existing socioeconomic and environmental conditions. It characterises the landscape development potentials and risks in the entire study area.

Moreover, satellite images fall short of capturing all of a community's land use objectives that are temporal but spatially inexplicit and the aspatial components that contribute indirectly to landscape evolving character. For instance, places of hunting and gathering of Shea fruits, honey harvesting and firewood picking cannot be captured by satellite images. Also, population expansion that imply accommodation, farmland and settlement expansion cannot be directly inferred from thematic maps. Therefore, during participatory mapping, communities also sketched timelines to illustrate the trends in land-use/land-cover change from 1984 to 2014. The timelines and sketched maps of the communities were also analysed to discover the number of houses/dwellings, social amenities such as schools, clinics, and dams, and their spatial distribution within the base period. The objective was to identify the patterns of physical growth of communities so as to envisage future displacements and the opportunities and constraints of resettlements.

2.2.5. Spatial extents of mining concessions

The extents of exploration/mining concessions were developed to determine their spatial interactions with local communities and to build knowledge over the uncertainties of displacement and resettlement. The concessions map was obtained from report 43–101 that was downloaded from the Azumah Resources website. Azumah Resources is an Australian resource company currently holding exploration and mining leases in the upper west region. The leases are labelled by the company with the names of villages where these are located. These data were digitized in ArcMap as polygon shape files. It would be noted that Azumah resources owns all eleven exploration and two mining leases in the region (Azumah Resources Limited, 2013). The company currently enjoys monopoly in the area.

Polygon shape files containing the study districts and point shape files of settlements in the districts were obtained from the Ghana Statistical Service. However, the Nandom and Nadowli-Kaleo districts were newly created in 2012, and therefore, did not have boundary delineations. Hence, the two new districts were demarcated by the local authorities on the historical maps of their former districts. The coordinates of the distinct boundaries were read on ArcMap and used to digitize the new districts from the former affiliates. The digitized leases map was then overlayed with the district boundaries for identifying their spatial distribution. The villages, whose names are used to label the concessions, as well as the districts where they are located, were then identified. Although it is estimated that one out of every ten exploration activities progress to mining (Singer and Kouda, 1999), exploration activities displace communities from investing further on lands under concessions (Cernea, 2003; Twerefou, 2009).

2.2.6. Landscape characteristics, dynamics and processes

Sonter et al. (2014b) identify that landscape character on an emerging mining region is defined by the concurrence of non-mining land use activities. To identify these land uses, data on the socioeconomic activities of the study districts and communities were obtained from the Ghana Statistical Services. However, detailed data about socioeconomic activities at a community level were inventoried during focus group discussions. The land use activities were further grouped into physical and economic activities. The physical activities comprise of dwellings, roads, clinics, schools and community centres. The livelihood activities of the communities that were inventoried were grouped into major industry sectors and used to validate the economic activities data at the district-wide level (Table 1). The 2008 revision, 4th edition, of the International Standard Industry Coding (ISIC) system was used to do the validation through a cross-tabulation of activity codes under industry types (Popkin, 1990).

The 2010 population data at the districts level were also obtained from the Ghana Statistical Service. However, from 1992 to 2012, there have been several partitioning of districts in the country, which affected the apportionment of census data. Therefore, the accompanying annual intercensal rate of increase (1.7%) corresponding to the year 2000 population census was used to calculate the population of the year 2000 for all districts. The same process was repeated to derive the 1984 population, using an accompanying annual intercensal rate of increase of 1.5% corresponding to the 1984 population census. Then 25 villages, whose

Table 1
Indicating validated results of livelihood activities and industries in the study area.

Activities	AGRICFF	MINQUA	MANUF	WRETAIL
Cropping	A0111			
Gardening	A0113			
Fishing	A0312			
Shea butter processing			C1030/1040	
Pito brewing			C1103	
Trading				G4620/4630/471
Food processing			C1075/79/106	
Wood carving			C1629	
Weaving			C1629	
Pottery and ceramics			C2393	
Sand/gravel/clay/stone Quarrying		B0810/08		
Haunting	A017			
Livestock keeping	A0141/44/45/4			
Firewood and charcoal			C1629	

AGRICFF = agriculture; MINQUA = mining/quarrying; MANUF = manufacturing; WRETAIL = wholesale/retail.
Source: Fieldwork.

census data from 1984 to 2010 were available, have been used to study the trend of increase in population of sampled villages.

The anticipated future landscape character, the driving processes during mine operations, and the associated potentials and risks of resettlements were also explored. To this end, future land-use/land-cover change was predicted for the first seven years of mine operation and the entire 15 years of lease permit using a Markov Chain and Cellular Automata (Markov-CA) model. The Markov Chain analysis assumes that the future state of the landscape can be predicted with relevant knowledge of existing and previous landscape conditions; and the cellular automata assumes that the future state of cell can be determined by the state of its neighbours (Eastman, 2003). The Markov-CA model uses pre-calibrated land-use/land-cover parameters to project future changes. To this end, the village maps, point shape files of sources of water and existing land-use/land-cover data were used to calibrate the model. The model produced a transition probability matrix, using the 2000 and 2014 Landsat images as the base years upon which it predicts the future land-use/land-cover changes for the entire study area. The transition probability matrix computes the probability that each land-use/land-cover may change compared to every other land-use/land-cover type within its neighbourhood (Eastman et al., 2005). The existing land-use/land-cover maps of the area (Duadze, 2004) were used to validate the quality of the predicted land cover map.

Giving land occupancy of exploration and mining concessions, the available space in each district was calculated and used to redefine the emerging population densities. The area of predicted available occupied lands was used with the emerging populations, using the following equation:

$$AFB_{Sd} = PredFBS_d - EL_{Ad} \tag{3}$$

where AFBS represents available occupied lands; PredFBS represents predicted occupied lands; A represents area, d represents district and EL represents exploration/mining leases.

The available occupied land per district was calculated by subtracting the total area of exploration leases from the predicted area of occupied lands in that district. The annual intercensal rate of population increase (2%) obtained from the 2010 population census in the upper west region was used to extrapolate the population of the districts and communities. As accustomed of mining regions, an anticipated urbanisation was also extrapolated starting from 2016 as the expected year of mine commissioning (Washbourne, 2014), for seven years and 15 years. In Ghana, mining concessions are granted for 22 years in trenches of seven years for beginners and 15 years for subsequent renewal (Gajigo et al., 2012; Minerals Commission, 2010).

In their study of mining as an intensive driver of land use change, Sonter et al. (2014a,b) found that the industry's land use expands at a rate of approximately 4 km^2 per year and cumulatively displaced up to 200 km^2 in the Iron Quadrangle mining region of South-east Brazil. There is no standard measure for analysing both displacement and resettlement options in mining regions. Hence, 2 km and 5 km buffers were created around the imminent mine operation areas in this study to appraise the potential on-site land displacement of nearby villages. The buffers were also created to identify the land-use/land-cover that would be affected; and the character and opportunities of landscape in adjacent communities that might be considered for resettlement. The buffers were overlaid with the 2014 thematic map and the sample villages land use extent map in the Nadowli-Kaleo district. The 2 km buffer showed the host communities of the mine operation area, and the 5 km covered adjacent villages next to mine host communities. These distances were taken based on the average area of villages in each study district.

3. Results and discussions

3.1. Landscape character, dynamics and processes

The minimum overall classification accuracy of the three dates (1986, 2000, and 2014) is 96%, 97% and 99%, respectively. Accordingly, the kappa index results are 95%, 96% and 99%. Fig. 3 and Table 2 show the dynamics of land-use/land-cover in the study area. Between 2000 and 2014 and the entire base period, 1986–2014, all the land-use/land-cover types decreased except for occupied lands. The transformations were most legible in the Wa-Lawra belt, especially, from the west of Jirapa to Nandom Districts (Fig. 3). Overall, the period between 1986 and 2014 showed massive transformations from all other land-use/land-cover types into occupied lands. These results support the biophysical descriptions of the Wa-Lawra belt by Adu and Asiamah (2003) and Blench (2006). [1]Compound farming was most prevalent in the Wa-Lawra belt, but less practiced in the Wa East and Wa West areas. The Wa East and West districts were more vegetated and waterlogged, with sparse occupied areas between 1986 and 2000 (Fig. 3).

However, as a result of growing populations and associated housing and economic activities (Figs. 4 and 5), such as illegal small-scale mining, the Wa East areas have also experienced expansions on occupied areas between 2000 and 2014. Transitions from vegetated areas to waterlogged areas could be attributed to bush burning and deforestation activities, which rendered the landscape bare (Duadze, 2004; EPA, 2003). Besides, soils in the area were generally muddy and wet during the rainy season (Adu and Asiamah, 2003). Thus, the results also agree with the findings of Duadze (2004), showing the Wa-Lawra belt land-use/land-cover as predominantly occupied and densely populated area and the Wa East as dominantly vegetated and waterlogged.

Fig. 4 shows that the population in all the districts increased steadily, from 1984 to 2010, and through to 2014. The findings support the hypothesis that land-use/land-cover changes observed in the study area, within the three decades, can be attributed to increasing populations (Fig. 4), which further increases demand for housing; infrastructure such as schools and clinics (Fig. 5); and increases in farmlands (Pham et al., 2015). The Jirapa district recorded the highest population increase throughout the period. It was followed by the Wa West and East districts. However, the trend was uncertain in selected communities; some experienced a decrease between 1984 and 2000, but increased in 2010. The fluctuations experienced on population trends in some of the villages were due to rural-urban migration (Marchetta, 2011). During the mapping, new buildings and roads were also identified on the timelines and community sketch-maps over the period. These patterns have implications for mining land use and associated urbanisation. Space for providing further accommodation for incipient mining-induced urban populations would be limited in the communities. This might extend pressure on existing farm and fallow lands, potentially leading to land degradation.

3.2. Constraints/potentials for mining induced resettlement

Fig. 3 shows the predicted spatial character of the study area within the first seven years and 15 years of mine commissioning. Note that areas that were vegetated in 2000/2014 would gradually change to waterlogged areas and occupied lands by the year 2022/2030. Most of these trends were visible in the North-west of the Nadowli-Kaleo District, where there is, currently, a mining lease

[1] Compound farming is the situation whereby local areas are intensively cultivated and farmlands are largely confined to the vicinity of settlements.

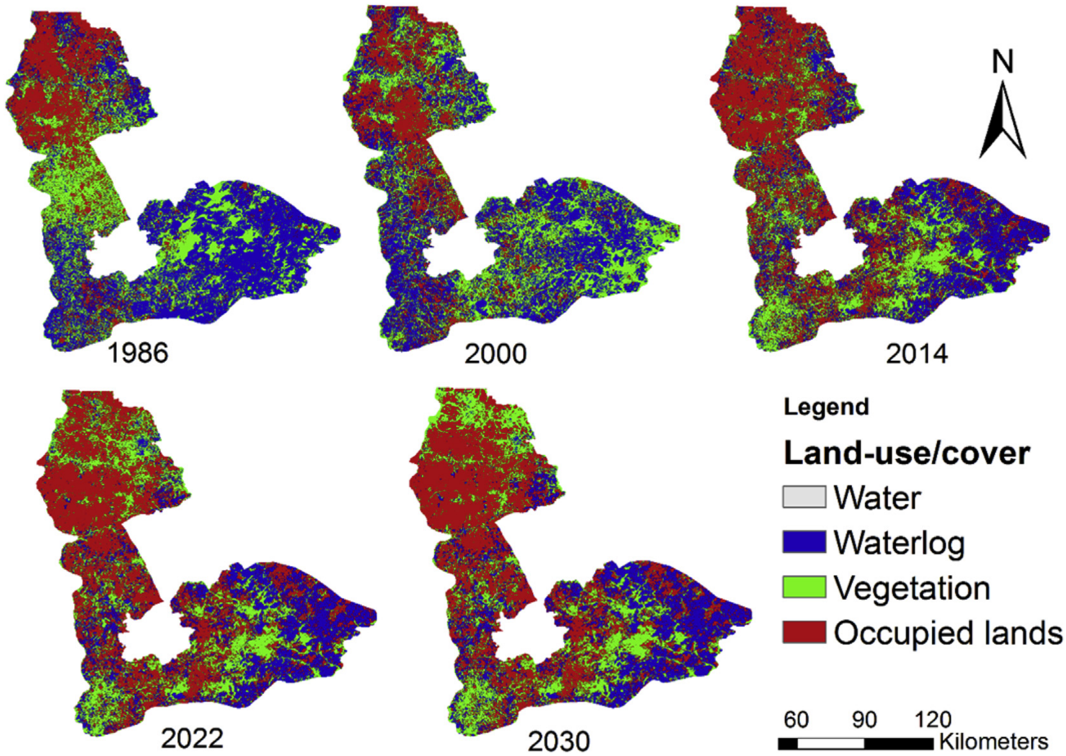

Fig. 3. Land-use/land-cover maps derived from Landsat images of 1986; 2000; 2014.

Table 2
Land-use/land-cover changes from 1986 to 2014; area in ha and %.

	LULC dynamics between base periods, in ha and %					
	1986–2000		2000–2014		1986–2014	
Water	153.0	24.1%	−200.7	−25.5%	−47.7	−7.5%
Waterlog	−32890.2	−7.9%	−108715.9	−28.4%	−141606.09	−34.1%
Vegetation	14573.5	4.9%	−58240.08	−18.8%	−43666.56	−14.8%
Occupied lands	18163.4	7.5%	167155.83	64.3%	185319.18	76.6%

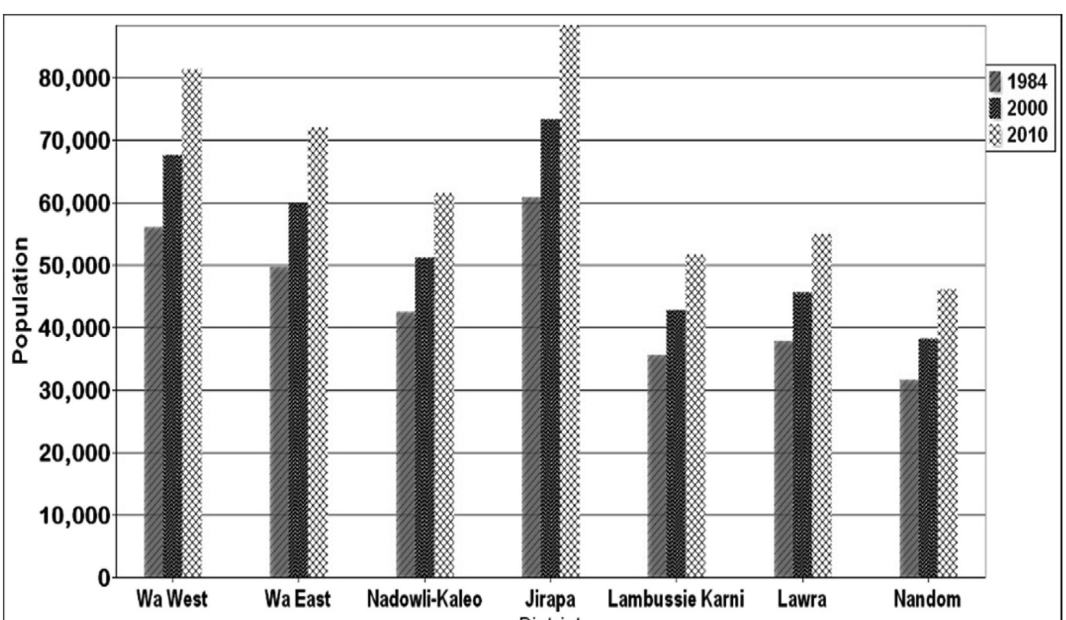

Fig. 4. Trends of population growth (by District).

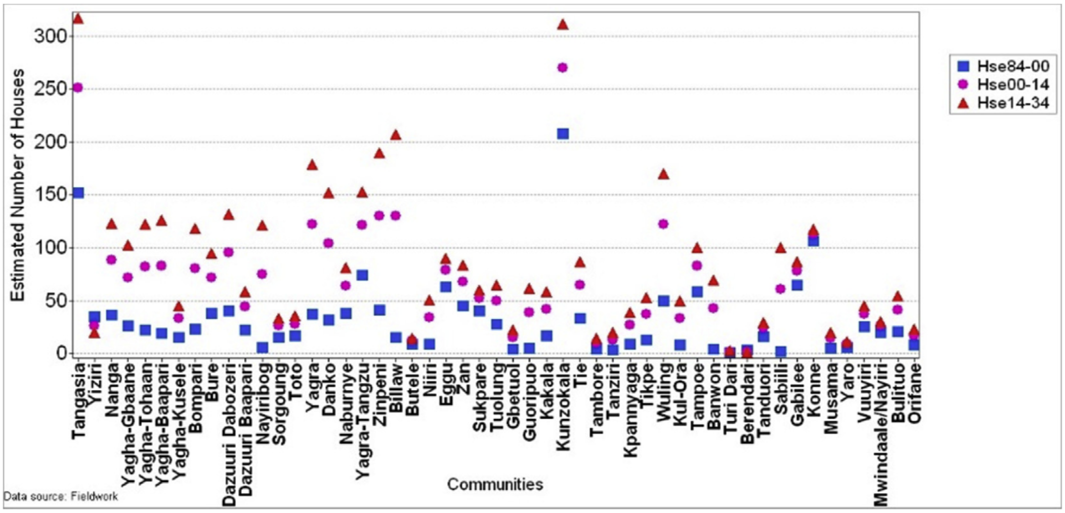

Fig. 5. Trends and projected housing expansion (for 20 years) at villages.

(Fig. 3). The Wa East district would experience the highest expansions on occupied lands due to an increasing population through small-scale artisanal mining and expanding farming activities. These observations were made during fieldwork. The areas west of Jirapa to Nandom and west of the Lambussie Karni districts were also principally occupied lands. These areas are widely cultivated Savannah lands, with high population densities and associated vegetation clearing (Blench, 2006; Duadze, 2004). Given the characteristics of waterlogging and drainage in these areas (Valipour, 2014), the spatial suitability for resettlement; both agricultural and non-agricultural livelihood activities could be explored. Waterlogged areas receded to the observed change trends (Table 2), and could be an opportunity for future agricultural activities. However, vast areas showing waterlogged patterns could be potential constraints for resettlement in the east of Jirapa and Wa East districts (Valipour, 2012b).

Fig. 4 shows the anticipated population growth of the area through a mining sector derived incipient urbanisation. With respect to the number of exploration leases granted, their sizes, and the predicted areas of occupied lands, the Nandom and Lawra districts would not have enough space for resettlement (Fig. 2). Comparatively, these districts have large exploration leases, coupled with smaller size of the district. Although the Nadowli-Kaleo and Wa East districts would be host to the emerging activities within the first seven years, they recorded relatively lower anticipated population growth (Fig. 4). These features are supported by the findings of Lentz (2006); that the Eastern portions of the upper west region have lower population densities, and large fertile agricultural lands than the western portions. Thus, during non-farm seasons, families depend on the sale of food crops and livestock products to provide basic needs such as school fees and hospital bills (Blench, 2006). This explains the disparities between livelihood activities in the area (Fig. 7). These characteristics could be harnessed, by governments and exploration/mining companies, for sustainable resettlement site selection and planning.

3.3. Relocation opportunities and constraints at the local level

Fig. 2 shows also the spatial interactions between local communities and exploration/mining concessions, and Fig. 5 illustrates the trend of residential expansions at the village level. It would appear that the exploration and mining leases dominate over whole communities, including external farms (Fig. 6). These trends result in an increasing insufficiency of land, within the immediate vicinity of mine operation areas, for relocation of farming and other non-farming activities (5 km buffer). Table 3 and Fig. 6 again show that the communities that are proximal to the mine operation area (2 km buffer) are privy to land use displacements in the event of mine expansion. Besides, about eleven sampled settlements fall within the 5 km buffer in the Nadowli-Kaleo district. These are Sabiili, Tanduori, Tuolung, Gabilee, Konne, Vuuyiri, Yaro, Tambore, Mwindaale/Nayiri Cherekpong, Wuchema, and Yagha-Tohaan with areas less than 10 km^2. The landscape character of these communities also show large occupied areas. Traces of potential flood hazards can also be found in these communities with respect to drainage and waterlogging (Valipour, 2012a), especially within the 5 km buffer. The 2014 thematic map of the Nadowli-Kaleo district shows some waterlogging in the east. However, this is not significant enough to hinder resettlement. Thus, the district profile confirms that communities in the east have more fertile lands than the densely populated western portions.

Anyhow, it is apparent from Table 3 and Fig. 6 that communities that are within 2 km of the mine operation area would have limited space for livelihood activities. These settlements would, therefore, have to relocate farmlands and other land associated economic activities. Meanwhile, from Fig. 6, it can be seen that communities within the 5 km buffer are already beset with bare and ostensibly barren areas. This phenomenon is not suitable for relocating displaced communities in the area. An inventory of livelihood activities in the districts and villages confirms that agriculture is the primary driver of the local economy, followed by manufacturing and the wholesale and retail sectors (Fig. 7). Most of the manufacturing sector activities directly depend on tree and plant harvests. For instance, about 100% of rural communities in the area use charcoal and firewood as sources of fuel energy for domestic and commercial activities (Adu and Asiamah, 2003; Blench and Dendo, 2004; EPA, 2003). Adu and Asiamah (2003) found that the fallow periods in the area have reduced from 10 to two years. These practices open the area to desertification, accounting for large bare lands and falling agricultural yield, especially in the Wa-Lawra area (EPA, 2003). Hence, the evidence provided in this study indicates that suitable sites for sustainable resettlement in the Wa-Lawra belt might not be feasible.

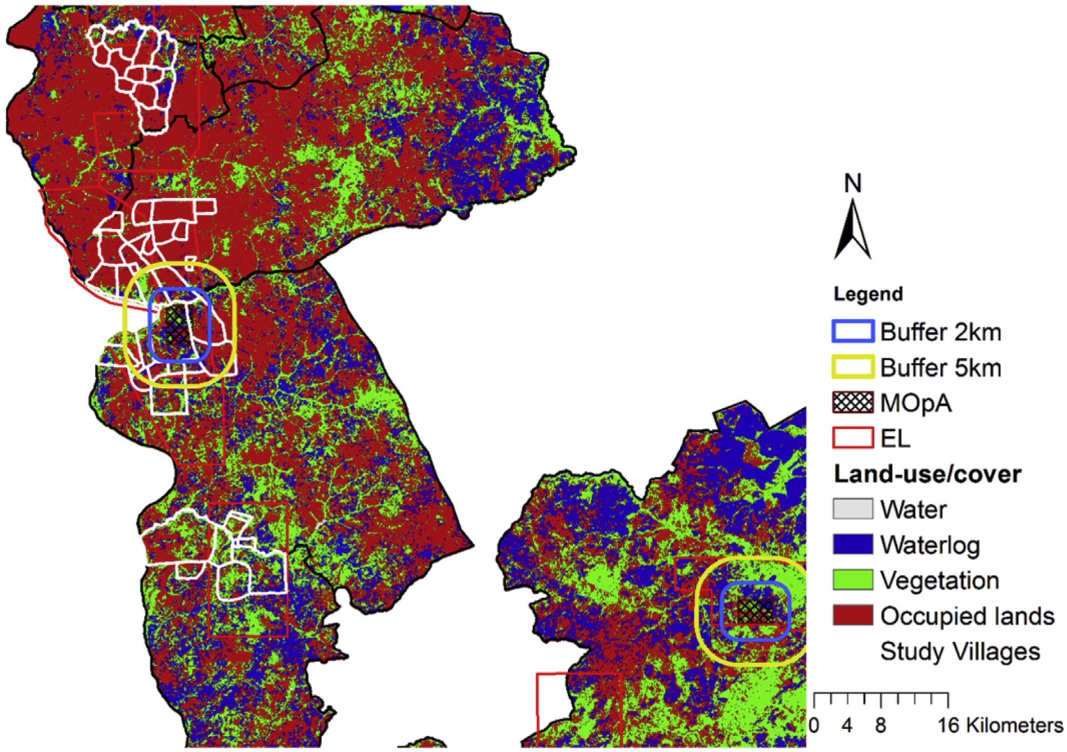

Fig. 6. Buffer zones of 2 and 5 km.

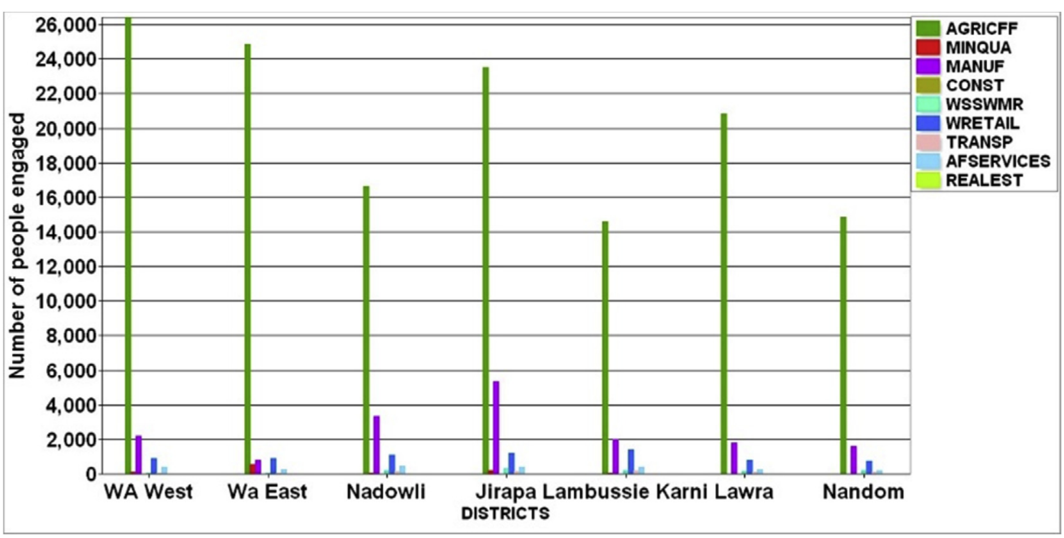

Fig. 7. Economic activities.

Table 3
Communities within 2 km buffer.

Community	Extents within buffer (Ha)	Village extents mapped (Ha)
Yiziri	1171	1767
Tangasia	325	1684
Kpannyaga	545	1305
Musama	38	300
Nanga	3000	3039
Orifane	300	1073

Source of data: fieldwork.

4. Conclusions

The study hypothesised that a Strategic Resettlement Feasibility Study can mitigate resistance and impoverishment of displaced communities in mining regions. To this end, the study examined the historical, current and future land-use/land-cover patterns to appraise the baseline conditions in the study area. Considering the location association between mining and urbanisation and the effects on local space, population densities were extrapolated to place the landscape opportunities and risks for supporting resettlement on a local and regional perspective. The study further used buffer analysis to identify the risks and opportunities of mining activities in an emerging area using both existing and predicted land-use/land-cover and livelihood analyses as surrogate measures. Thematic maps of the area developed from satellite images from 1986 to 2014 showed a consistent trend of expansions in occupied areas. The east further showed parallel trends including vegetation cover expansions over waterlogging. But the current extents of waterlogging in the eastern portions might not be suitable for intensive agriculture and population resettlement. The buffer analysis showed that there are limited opportunities for sustainable resettlement of displaced communities in the Wa-Lawra belt as compared to the other districts.

The findings of this study would be useful for resettlement and post-mining land reclamation planning in the region. The results also provide comprehensive geospatial data that is usually lacking, especially at sub-national levels in developing countries (Cuba et al., 2014). In particular, the geospatial data could augment existing data for efficient spatial planning at the local government level. It sets the benchmark indicators for monitoring and evaluation of mining sector activities and for validating the environmental and social impact statements of projects in the area. The results would also be useful for flood hazards management, and rural land use planning. Furthermore, the findings of this study support the African Union's declaration of its commitment to support member countries to achieve optimum management of natural resources without compromising the livelihood and food security of communities (African Union, 2005; African Union, 2014).

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jclepro.2016.06.004

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CHAPTER 9 General Discussions and Conclusions

This chapter provides a summary of the problem, brief discussion of major findings, conclusions, and recommendations for future research work.

9.1 Introduction

This study probed the spatial perspectives of the dynamics of resistance against the future of the mining sector in Ghana's emerging northwest gold province. Land as a natural resource provides the basic necessities of human societies, especially in rural areas. Examples include food, both surface and groundwater, and shelter. Being a finite resource, increases in the accessibility of land for resource creation by one sector decreases the opportunities of other users. In particular, globally, natural resource occurrence and development is a rural phenomenon (Yaro 2010). Trends of increasing demand for rural land for mineral resource extraction reduces its availability for primary production and rural livelihood, which stimulates resistance (Joyce and Thomson 2000). Overall, the contributions of agricultural and non-agricultural livelihood activities of rural areas to the economies of developing countries cannot be underestimated (Ellis 2000). However, mineral resource development is a high-stakes industry that is associated with risks to rural communities and high-value ecosystems. Thus, the impacts of mineral resource development are pervasive and enduring to local communities in developing countries (Kumah 2006; Twerefou 2009).

Meanwhile, it is believed that developing countries can achieve economic growth and industrialization through diversified economies resulting from the mineral resources sector (Africa Mining Vision, 2009). Accordingly, the synergy and co-ordinated contributions of all viable resource sectors are required for the economic liberation of developing countries, rather than the unilateral contribution of one sector (Shaw 2015). Therefore, the models developed in this study are tailored towards addressing local concerns, and examining local resource development challenges for an optimum beneficiation of the mining sector development. It should be understood that in rural environments, everything is related to everything else as is the first law of geography (Tobler 2004). Thus, the study recognises land use conflicts in mining regions as a function of displacement of socioeconomic and environmental resource-base of the communities (Fig. 8.1). The study involved a multi-sectoral examination of space between the mining industry, agricultural, non-agricultural, physiographic and other minor sectors that affect the lives of rural people, using the SEE MODEL (Socio-Economic and Environmental).

Consequently, this chapter discusses these multi-objective spatial interactions and displacements. It reviews the various specific objectives of the study and highlights its main findings. Furthermore, the chapter analyses the ways in which the study's findings could be applied for managing potential land use conflicts between local communities and the mining industry in the study area. Finally, this chapter draws conclusions and makes some recommendations for future research that would consolidate the findings of the current research. This would be necessary for long-term planning of mineral resource development projects in developing countries.

9.2 Multi-objective space modelling

The model below summarises the analysis and findings of this study. It represents space, identification of land use activities and environmental contingencies in mining regions. Land use activities include socioeconomic activities and mining interests. The inverted triangle represents analysis of the spatial interactions between agricultural land use and the mining sector activities from the macro-level (district) at the top, and narrowing to the micro-level (village) at the bottom. The vertical triangle represents analysis of the spatial interactions between non-agricultural land use activities and the mining sector, from the micro-level at the tip-top to the macro-level at the bottom. The circle represents the mining industry's land use interests. The bi-directional arrows show the diffusion of negative impacts, and opportunities between local communities and the larger district and region. The square formed in between the two triangles and the circle indicate mine operation areas (MOPA), where communities' land use interests would be displaced and must necessarily be relocated.

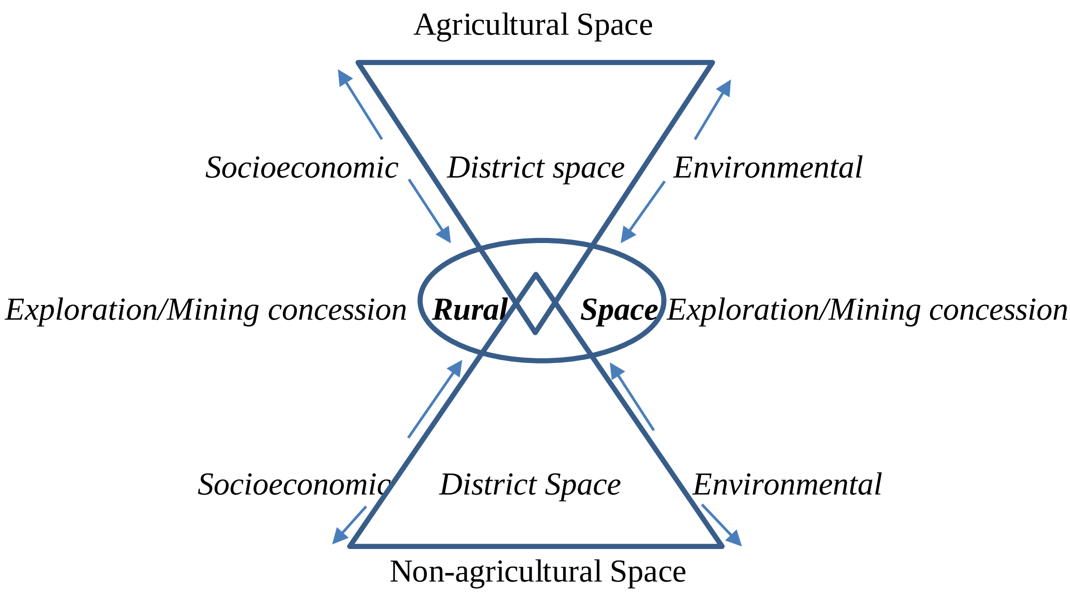

Figure 9.1 Multi-objective Space model of land use for mediating N-persons non-zero sum rapport between local communities and mining companies

Land tenure systems in the region vary from group to group, but it is basically based on inheritance through the village lineage and cannot be sold or bought. Individual land ownership is not practiced but an individual may have strong farming rights over family land. Thus, communal land rights are well preserved in the area and must be recognised as such for any land use development objective. In view of this, land use planning in the region has remained an ideal policy since families determine the use of land. Considering options for relocation of land use activities, a threshold should be cast outside the circle else, future discoveries, if possible, would again destabilise communities and livelihood. But a permanent solution to displacement would be desirable, which is feasible outside the circle. The implications are that, communities would experience social disintegration since they would no longer have access to their native land and its cultural symbols such as shrines and family ties. Communities outside the circle but within the same district would also have to adjust space since previously occupied areas would be minimised to share with those displaced. Examples include bush fallowing and land rotation, which are crop farming practices. Such space re-adjustments could be negotiated by the district assemblies.

While it may be concluded that mining regions lose rather than gain (Pegg 2006), the study illustrates that the benefits of mineral resource development can be optimised in developing countries with efficient management of resistance and conflicts. Resistance in this context could be the indisposition of the mining industry and policy decision makers to modify approaches that stipulate mining and land use. This is demonstrated in the array of methods and tools used to answer the main questions of this study. The socioeconomic and environmental (SEE) approach was used as an efficient platform for co-ordinating between the research objectives, analysis and discussions based on an evaluation of the scientific relevance and usefulness of the research methods.

From the fieldwork, it was noticed that exploration and mining concession licenses are granted without a prior consultation and sustained participation of local communities, who are the de facto land users and owners. This instigates growing tensions between companies, governments and customary land owners. Besides, local governments and communities lack the necessary capacity to generate spatial data for effective resource management and negotiation processes in most developing countries (Amanor et al. 2005; Mankelow et al. 2001). This affects their ability to understand and engage governments, exploration and mining companies in constructive negotiations. Without this elementary capacity, it is also difficult to understand local communities' land use values and objectives in their right perspectives. Thus, the protocols employed during fieldwork exposed community members to issues worth discussing within themselves, and with governments and companies.

9.3 Specific Objective 1:

Develop methods for identifying the potential land use impacts of current exploration and future mining activities on local communities' livelihood; and analyse the efficacy of local stakeholders in addressing issues emanating from these defects

It may be perceived that rural communities are homogenous in resource creation. However, variations exist among them in respect of harnessing resources and development objectives. Some communities have economies dominated by agriculture; others have mining and quarrying, small-scale low value mineral mining, and localised manufacturing. Some are well endowed while others are poorly endowed. Thus, the problems, needs, and development potentials of local communities vary and may be locally sensitive. These variations determine the levels of resistance and conflicts over mineral resource development.

Spatial interactions between mining, agricultural and non-agricultural livelihood activities

Firstly, the study provides empirical recognition of the claim that agriculture is the dominant rural livelihood in sub-Saharan Africa (Ellis 2000; McIntyre 2009). This is explained using location quotient (LQ). Agriculture has an LQ >1 in all the districts and villages except the Jirapa district. This gives a typical estimate of the importance of the sector, and the magnitude of impacts that a mining-induced displacement can have on the agriculture-based social and economic network systems of rural communities in the area. More people are inclined to agricultural production, which is typically land based. Although the Jirapa district records an LQ<1, it was noted during fieldwork that agriculture remains the backbone of economic livelihood in the area.

A hybrid approach is used by combining agricultural suitability assessment with the mining industry concessions in a Geographic Information Systems (GIS) environment. Land occupancy of mining concessions and agriculture are normalised and quantified. A combination of these techniques provides an efficient measure of the suitable agricultural land that is potentially displaced by the mining sector activities in each district (Chapter 2). Agricultural suitability in the landscape is assessed to delineate and accurately measure viable agricultural land use in the area. The objective was to identify agriculturally unsuitable areas that could be transformed to support those who shall potentially be displaced from productive lands.

The findings show that the minimum cultivable lands intercepted by mining and exploration concessions is 8916 ha, which translates to a minimum of 639 crop farmers potentially displaced in a district-wide perspective. However, the results show that at least 90 ha of cultivable lands would be displaced at the village level. It is observed that concessions cover the whole of some villages. Thus, these villages would have to be relocated, should exploration translate into mining. Already, some of these villages complained of interference on their farmlands by exploration companies. This report was gathered during focus group discussions at the communities. Analysis of the spatial interactions between localities and the concessions, therefore, provides insights into the realities on the ground. This knowledge could enhance the District Assemblies' (DAs) land use planning in order to forestall future impacts of the mining sector on agriculture. Thus, the knowledge empowers the DAs to properly engage both companies and central governments on the modalities of compensation schemes, should feasibility studies be successful. Early engagements help to define the role DAs have to play in: (i) mediating alternative livelihoods for the potential displaced people and, (ii) land use conflicts between local communities and future mining companies.

Furthermore, a strong location association (La> 60) has been found between agriculture and all other livelihood activities, except mining and quarrying, at both district and village levels. The La results further explains the importance of space between a multiplicity of livelihood objectives of rural communities in the area. For instance, agriculture, which is a dominant livelihood activity in the area, has a La> 60 with wholesale and retail, and manufacturing at both district and village levels. Thus, a mining sector-induced (whether exploration or extraction) cultivable land displacement would not only affect crop farmers but, other people such as traders, brewers, and food vendors. For instance, during fieldwork, youth of some of the villages near exploration sites indicated that the company's operations are affecting shrubs and trees that provide herbal medicines, which is source of income for them.

On this basis, these youths could be engaged, with the spatially-based results of this study, to help in the land use planning of the area so as to avoid livelihood disruption that would lead to violent confrontations between community youth and exploration companies. It is novel in the country to have such models of rural space for assessing the interactions between local communities and the mining sector land use interests (Cuba et al. 2014).

Although agriculture has an LQ>1 in most of the districts and communities, the emerging effects of climate change on agricultural productivity gives vent to the diversification of rural economies, which still depends on agro-based sub-industries (Yaro 2006c). Thus, an LQ>1 for the manufacturing sector shows that it is another important livelihood activity in the area. Tree based manufacturing activities such as charcoal burning, fuelwood, wood carving and the direct harvest of fruits provide a major source of income to rural people during off-farm seasons (Blench and Dendo 2004). The Shea processing industry is the most developed among all tree based sectors in the area (Hatskevich, Jeníček and Antwi Darkwah 2011). However, considering the spatial relations between Shea trees and farmlands in sub-Saharan Africa (Schreckenberg et al. 2006), a sector would be directly affected by land displacement. During fieldwork, women in most of the study villages indicated that the exploration company does not discriminate between economic trees such as the Shea and other non-viable species.

However, the study of Yidana (2004) suggest that there are opportunities for adopting the Shea tree planting across the northern savannah regions, which could be an effective form of alternative livelihood, given its growing global importance (Carette et al. 2009). Thus, areas identified as unsuitable for crop cultivation could be adopted for Shea tree planting and butter production. This initiative would offset the direct effects of displacement and thwart temptations of land use conflicts. Overall, the study tests the importance of these other economic livelihood activities of rural communities and measures the risks and uncertainties associated with mining sector-led displacement. It assessed the uncertainties of decapitalising local communities, through *Shea* dominated local manufacturing sector displacement, as another basic rural livelihood activity worth recognition in negotiation processes. Importantly, the study offers opportunities to visually identify the livelihood risks and uncertainties at the early stages of mineral resource development for mitigating impoverishment and conflicts (part 1). Moreover, the adoption of Shea tree plantation development would also be a strategic approach for curbing sensations of mining-induced land degradation in the area.

9.4 Specific Objective 2

Develop models for assessing exploration and incipient mining operations conditions that would contribute to the development of both typical and atypical environmental stress, generating social disruptions and disputes

The environmental stewardship of the mineral resource sector has been one of the major issues affecting the sector's relations with local communities (Azapagic 2004). The sector's unhealthy interactions with the environment is a hot area of global debate. The mining industry has been associated with reductions in soil fertility, soil erosion and nutrient loss, deforestation, and water pollution (Aragon and Rud 2012). Hence, with a rising environmental conscience in developing countries, this study models the major ways in which the mining industry may be resisted for its unhealthy environmental stewardship. Local governments that act on behalf of local communities do not have the technical capacities to conduct such pre-mining surveys in the area (Carson 2005).

Potential Mining Induced Land Degradation and Displacement (MILDD)

Apart from the direct displacement of land use activities, the mining industry associated activities such as road construction, site clearance, and infrastructural development indirectly displace land use activities through the initiation of land cover loss and erosion. Hence, the study assessed and mapped potential land cover removal; and envisaged the risks of soil erosion by water and its impacts on both agricultural and non-agricultural socioeconomic activities. On mining concessions, at least 225 trees and 24827 kg of shrubs and grasses have been cleared for construction. It is further estimated that at least 2432 trees and 22902 kg of shrubs and grasses would be displaced through exploration and possible mining activities in the area. These potential disturbances would affect at least 13 rural households, which might increase to about 79 in the first 6 years of mine operation and expansion.

In comparison, Nkonya et al. (2011) estimate that land degradation displaces about 1.5 billion people and about 1.9 billion hectares of land globally. Consequently, it is estimated that about 24 billion tons of fertile soil is lost annually through land degradation, and its associated desertification hazards affect up to 23 ha of fertile per month, (Nkonya et al. 2011). It is further suggested that about 74% of the world's poor are affected by land degradation, although these are not directly attributed to mining. However, Aragón and Rud (2015) found that near mining areas in Ghana, agricultural productivity decreased by 40% relative to areas farther away, and households become relatively poorer. These effects are attributed to the degradation impacts of mining. Nonetheless, the observed potential effects of mining-induced land degradation and related conflicts could be addressed alongside project planning (Cernea 2003a).

To this end, Mining Induced Land Degradation and Displacement (MILDD) (in Chapter 5) has been proposed as a new concept and explained to capture estimates of the indirect impacts of mining sector development on both economic and non-economic livelihood (Ellis 2000). That is by analysing the total area of concessions and their interactions with ecosystems goods and services (Nachtergaele et al. 2010). The study established this relationship by integrating the Fournier erosivity analysis with GIS. It remains inevitable that exploration and mining activities displace trees and grass cover, thereby, exposing land surface to direct contact with both water and wind erosions. However, the focus is on land erosion by water since it is the dominant type of consequence in tropical Africa (World World Bank 2006).

The Iso-erosivity map developed provides a microscopic understanding of the implications associated with mineral resource development in a regional perspective. The analysis found that areas granted mining leases fall within environments under high risks of erosion (43-60 mm). Importantly, areas with large vegetal removal and high population densities fall within the high erosivity risk zones. These areas could be considered as largely conflict prone areas because, the conditions cannot support a synergy of mining and agricultural production. Nonetheless, it provides opportunities for efficient mine closure and land reclamation planning at the district level, since the results reveal that the entire area could be vulnerable to the effects of land degradation. Coupled with the Iso-aridity map developed in chapter following chapter, these findings are further supported by those of the EPA (2003) that the Wa-Lawra belt is a drought and desertification vulnerable area.

Mining Induced Water Stress (MIWS)

In developing countries, particularly in tropical Africa, water stress and water scarcity are intense due to lack of resources to extract both surface and groundwater for domestic, industrial and commercial uses, unavailability of water in aquifers or deep aquifers, lack of water treatment capacity and other environmental issues (UN-Water 2015). Meanwhile, mining processes consume large volumes of water and, thus, contribute to the water stress situations of host communities (Toledano and Roorda 2014). Hence, the study modifies existing water stress models and combines them with GIS tools to analyse the existing status of water stress in the study area. This sets benchmarks for measuring the impacts of the mining sector activities on water systems affecting non-economic and economic livelihoods.

Thus, the study proposes (in Chapter 6) a new concept for understanding, first of all, the water situation of mining regions prior to approvals of mining sector projects. Then, cognisant of the volume of water requirements in mining processes, the impacts of the sector on socioeconomic activities and livelihoods are estimated. Using the Iso-aridity map developed from the water stress indices, areas that are vulnerable to water stress within exploration and mining tenements are identified. This study delineated the region into aridity categories and found that some parts of the concession areas in the Wa-Lawra belt are within <0.5 aridity index. Hence, these areas are prone to drought. The impacts associated with these vulnerabilities are predicted for mitigation. Overall, the region has <0.2 mm of water stress status prior to mine commissioning, which is an indication of low stress.

However, existing conditions can be aggravated through over abstraction, stemming, pollution and Acid Mine Drainage (AMD) (Toledano and Roorda 2014), especially in communities that largely depend on surface water for drinking and domestic purposes. In the light of these effects, conflicts are predicted within local and regional drainage basins. These provide a shared knowledge that can facilitate the development of efficient water-use plans in the region. District Assemblies and central government agencies can use the models developed in this study to test and validate the water use plans and EIAs of companies.

9.5 Specific Objective 3

Identify areas of high environmental sensitivity and cultural value for supporting sustainable resettlement of potential displaced communities

Landscape suitability analysis for potential resettlement

The looming extensive production of mineral commodities in developing countries has considerable displacement and resettlement implications. Decisions to mine on a particular land in a region begin with exploration activities until viable deposits are identified for extraction. Indirectly, the decision to relocate a particular land use activity or resettle a community starts long before actual displacement and relocation (Cernea 2003a). However, this risk is not usually envisaged together with exploration and mine planning, leading to enduring unsustainable resettlement schemes in developing countries. Moreover, the emergence of mining activity introduces new competition for: agricultural lands, urbanisation in previously rural communities, and additional lands for other activities. This does not only pose a threat to rural livelihoods but also has implications for food security.

Coincidentally, the destinations of most extractive sector activities are often food insecure regions, raising concerns that fertile lands are being converted to large-scale digging while communities relocate into regions with less productive soils (Obara and Jenkins 2006; Schueler, Kuemmerle and Schröder 2011). This limits the capacity of local communities to meet basic needs such as food and water. Therefore, this research uses a systems engineering approach to fossick spatial suitability for supporting agriculture, non-agricultural productions and, incipient urbanisation in the event of mining-induced displacement and resettlement. The study shows that areas leased for exploration and mining activities are inaccessible for other land use activities and are, hence, unproductive to communities. The rest of the space in a district is then assessed as alternative productive land that would support agricultural and non-agricultural livelihoods.

In this regard, the study predicts three scenarios of emerging land use and resultant conflicts: (i) reduction in agricultural lands, (ii) expansions in residential lands and (iii) increases in environmental hazards. Earlier studies find that large-scale mining induces immigration, new population densities and land scarcity (Akabzaa and Darimani 2001). The conversions of existing agricultural lands and fallow lands into mining and its auxiliary activities reduces space for crop farming and livestock keeping. This reduces fallow periods, indirectly leading to low soil fertility and reduced production (World Bank 2006). Urbanisation has strong association with demand for land for the provision of accommodation and infrastructure. This further moves agricultural and non-agricultural livelihood activities into areas unsuitable for production (Kusimi 2008). Thus, the first two scenarios combined degenerate unsustainable production, increasing risks to environmental hazards such as deforestation, erosion and flooding. Districts with large areas of mining leases are prone to flooding and therefore, unsuitable for relocation. But with a visualised extrapolation of the landscape in the event of mining, potentially affected communities are easily identified. Therefore, a multi-sectoral planning would be required to select the most environmentally sound and sufficiently endowed space for relocation of livelihood activities or physical resettlement of communities.

Integrating the physiographic variables modelled in Chapters 5 and 6 shows disparities in landscape suitability to sustain large-scale mineral resource development, and agricultural and non-agricultural livelihood productions in the study area. Whereas the east of the study area has high flood risks, erosional effects, and water stress, it has vast suitable agricultural lands. On the other hand, the western sections of the study area have low water stress and flood risks but can be jeopardized with increasing loss of vegetative cover. The study shows high aridity incidence in this area, which is an indication of draught and potential of desertification. This phenomenon is detrimental to sustainable livelihood, food security and thus, informs the need for advanced afforestation and reclamation planning.

The study provides evidence for mine design optimization, resettlement planning and negotiations. The UN Economic Commission for Africa (UNECA) and the African Union (AU) are of the view that, food insecurity in most mineral resource-rich developing countries could be balanced with the returns of the mining sector (Africa Mining Vision, 2009). However, this motive would be meaningless to local communities if sustainable resettlement cannot be optimised.

9.6 Conclusions and recommendations

From the foregoing, it suffices to conclude that the general objectives of the study have been achieved. The study successfully established and analysed patterns of potential land use conflicts, applicable conflicts mitigation and impact assessment benchmarks in a spatial perspective. Specifically, the study developed models that made it possible to:

1. Identify and map the magnitude of mining sector impacts on a diversified local economy and its associated resistances;
2. Establish indices of mining sector-led environmental issues and associated potential conflicts;
3. Predict local space optimisation and a regional perspective on suitability assessment for sustainable resettlement of future displaced communities.

However, during the course of this research new areas, requiring further investigations, were discovered. If pursued, the findings of these new areas would contribute to the African Mining Vision's goal of developing a mining sector that would ensure that communities see real benefits from large-scale industrial mining and that their environment and livelihood are protected (Africa Mining Vision 2009). These areas include:

1. Detailed mapping of land-use/land-cover features at the village level. There is the need to delineate land use and land cover maps of all the villages under mining concessions. Most villages do not have any idea that their farmlands and sacred sites have been granted for exploration activities. Even the exploration companies have no idea of the spatial extents of adjacent villages that their activities will displace. In the long run, this could thwart efforts at developing sustainable relations between companies and local communities.
2. Integrating environmental and socioeconomic considerations with the mining sector planning at the regional, district and grassroots levels. Well-developed land use/land cover maps of villages could also enhance mine design, small-scale low value mining of minerals (LVMM), and artisanal small-scale mining (ASM) sector planning and coordination. At the moment, this is poorly developed in the area. There is also a dearth of up-to-date geospatial data on environmental and socioeconomic conditions in the area. These data are important for mediating sustainable development, land use planning; a balance between the mining sector and forward and backward linkages of local environmental resources such as charcoal and honey production.

3. Developing geographic information systems to meet tenurial issues, planning, policy formulation, decision making, and land-use conflict management needs of the region. The valuation of lands belonging to communities for compensation purposes need accurate spatial measurements. Post-mine land reclamation planning also requires a subjective land suitability analysis and consensus. However, district assemblies and local communities do not have such coordinated efforts that can provide meaningful negotiations with companies. Hence, district assemblies might not be able to act on behalf of the local communities that they seek to represent and to protect individuals against future livelihood disarticulations. There are no existing farmland inventories, and account of individual ownerships or family lands and ordinary occupants of such lands that are potentially trespassed by exploration and mining activities. Such information is a key determinant of sustainable compensations and land use conflict mitigation. Hence, the psychological preparations of villages towards accepting the future realities of livelihood disruption by mining companies might be underestimated.

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APPENDIX B STATEMENT OF CONTRIBUTIONS BY OTHERS

This thesis presents five first author and one single author refereed journal and conference publications. The statement in this Appendix identifies the contributions of author and co-authors to these papers. Both author and co-authors signatures are duly appended accordingly.

To Whom It May Concern

I, Abdul-Wadood Moomen, conceived and wrote the manuscripts, generated the data, designed and developed the models. Dr. Ashraf Dewan and Dr. Robert Corner provided critical reviews and guidance, giving the papers their unique qualities as duly accepted and published. All the above hold for the following publications:

1. Moomen, A. W., and A. Dewan. 2015. "Mining, agricultural space and land use conflicts: The role of local government." Agro-Geoinformatics (Agro-geoinformatics), 2015 Fourth International Conference on, 20-24 July 2015. DOI: 10.1109/Agro-Geoinformatics.2015.7248103

2. Moomen, A.W. 2015. "Quantifying Potential Socioeconomic Displacements and Land-use Conflicts in Prospective Mining Villages in Ghana." WSEAS Transactions on Environment and Development, Volume 11, 2015, Art. #35, pp. 325-342

3. Moomen, Abdul–Wadood, and A. Dewan. 2016. "Analysis of spatial interactions between the Shea industry and mining sector activities in the emerging north-west gold province of Ghana." Resources Policy 48:104-111. DOI: http://dx.doi.org/10.1016/j.resourpol.2016.03.001.

4. Moomen, A.W., and A. Dewan. 2016. "Assessing the spatial relationships between mining and land degradation: evidence from Ghana." International Journal of Mining, Reclamation and Environment. In Press. http://dx.doi.org/10.1080/17480930.2016.1188253

5. Moomen, A.W., and A. Dewan. 2016. "Investigating potential mining induced water stress in Ghana's north-west gold province." The Extractive Industries and Society. Doi:10.1016/j.exis.2016.04.002

6. Moomen, A.W., A. Dewan, and R. Corner. 2016. "Landscape Assessment for Sustainable Resettlement of Potentially Displaced Communities in the emerging Ghana's Northwest Gold Province." Journal of Cleaner Production. doi: 10.1016/j.jclepro.2016.06.004

And, I, Abdul-Wadood Moomen, contributed to all numerical and graphical results as duly published.

Abdul-Wadood Moomen ____

I, as a Co-Author, endorse that this level of contributions by the candidate indicated

above is appropriate.

Ashraf Dewan, PhD

____

Rob Corner, PhD_________________

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02/05/2015

Dear Abdul-Wadood Moomen ,

The Agro-Geoinformatics 2015 Scientific Committee has completed the review process and we are pleased to inform you that your manuscript #22, titled 'Mining, Agricultural Space and Land use Conflicts: the Role of local Government ' has been ACCEPTED as an oral presentation.

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Thank you and we look forward to seeing you in Istanbul, Turkey!

Agro-Geoinformatics 2015 Scientific Committee

LIST OF FIGURES

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