Impact of Land Use on River Systems in Ghana

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Abstract

Rivers play significant roles in the provision of water for domestic and industrial purposes. Nevertheless, land use dynamics continue to impact on river catchments which have negative repercussions for river health. This study focuses on land use change in the Okyeman Traditional Area, which encompasses three major river basins namely, the Densu, the Birim and the Ayensu. The study was aimed at investigating causes and impacts of land use change within the three river catchments and how these impacts could be curtailed to safeguard river health and sustainable water supply. Data for the study was derived from analysis of remotely sensed Landsat 7 ETM satellite imagery, and from questionnaire administration. Additional information was culled from the existing literature on land use, land use change, land cover change and related subjects. One major finding was that most of the river basins have undergone massive transformation over the last three decades as a result of various land use activities. The dominant land use types in the basins presently are agriculture, urban development, grazing, residential and transportation and fishing. The study also revealed that mining, indiscriminate waste disposal, water extraction and deforestation for fuel wood and other domestic uses, excessive use of chemical fertilizers and land degradation due to improper agricultural practices are also major land use activities that impact negatively on the river systems. The study concluded that there is the need to streamline land use activities, conserve vital ecosystems like watershed areas and maintain buffers along stream channels as a matter of policy to ensure adequate protection of aquatic fauna and to ensure sustainable water supply.

Introduction

The Okyeman traditional area encompasses three major river basins namely the Densu basin, the Birim basin and the Ayensu basin. These river systems play very significant roles in the provision of water for domestic and industrial purposes in communities and townships within their respective catchments. Nevertheless, human activities continue to impact on their catchments leading to land use change and deforestation. As a result, there is widespread catchment erosion and subsequent river sedimentation, water shortage, pollution, and other physico-chemical impacts not only in the regions immediately affected by deforestation, but also in reasonably distant areas (Hill, 1999). Ansah-Asare, (1995) enumerated the cascading effects of catchment degradation and other disturbances on water resources as nutrient enrichment of surface water from urban sources and agricultural chemicals, sediment loading caused by deforestation and euthrophication. Inappropriate water abstraction for domestic use and for irrigation within the catchment is also a great source of worry. All these impacts invariably have telling consequences on river systems and aquatic ecosystems.

Generally, the magnitude of anthropogenic transformation of landscapes resulting in land use change has been a matter of grave concern in recent times. Some researchers believe that the rate of transformations within a country's landscape are the direct result of population growth and pervasive poverty (Anderson,

1996, Mather and Needle, 2000, Boakye, *et al*., 2008). Lambin, *et al*. (2001) refuted the population and poverty-drive deforestation hypothesis, describing it as too simplistic. They opined that peoples' responses to economic opportunities, as mediated by institutional factors, orchestrate land-use changes. In other words, opportunities and constraints for new land uses are created by local as well as national markets and policies. They pointed out that global forces become the main determinants of land-use change, as they amplify or attenuate local factors. One school of thought used the I=PAT explanatory framework to highlight the three primary Influences responsible for land use change. These are Population, level of **A**ffluence and level of Technology. These influences are referred to as regional driving forces of change as events in one location impact on land use in other locations (Sage, 1994, DeHart and Soule, 2000, McCusker and Carr, 2006). Geist and Lambin (2002) however argued that driving forces are not only regional or global in scale, but also local. Proximate driving forces according to them relate to actions at the local level that directly affect land cover. Underlying driving forces on the other hand are global in scope and relate to fundamental social biophysical processes like human population dynamics or agricultural policies that reinforce the proximate driving forces and operate either at the local level or reflect influences at the global or national level. They also identified mediating factors which they described as forces that "may shape or modify the interplay between these two broad groups of causative factors" (Geist and Lambin 2002, p. 817)

Another school also believes that industrialization is the main drive towards land use change. According to this school, industrialization has brought about the concentration of human populations within urban areas and the depopulation of rural areas, accompanied by the intensification of agriculture in the most productive lands and the abandonment of marginal lands (Ellis and Pontius, 2007). Other writers believe that land use change is often the result of a combination of anthropogenic pressures (e.g. population growth) and natural factors such as variability in climate (Guerra *et al*., 1998; Janetos and Justice, 2000).

In this paper, we argued that the driving force of land use change is place-specific and influenced by the nature of rural economy. In traditional agrarian economies like Ghana where over 60% of the population depends directly or indirectly on agricultural land for livelihoods (Udo, 1978), land use types are always influenced by local livelihood demands.

Irrespective of the causes of land use change, their impacts could be very devastating on river catchments, and could result in loss of biodiversity through habitat loss, habitat fragmentation, and edge effect, which has the potential to affect interior species' viability (Ellis and Pontius, 2007). Soil erosion could also lead to loss of soil fertility in crop land areas and deterioration in water quality through sedimentation. Nutrient discharge through inappropriate use of agrochemicals and bush burning may also result in euthrophication and high nutrient loads. Deforestation by itself has the potential to impact negatively on climate change through the loss of carbon stocks (IPCC, 2007).

Land use is a complicated term, which

natural scientists define in terms of patterns of human activities such as agriculture, forestry and building construction that alter land surface processes including biogeo-chemistry, hydrology and biodiversity. Social scientists and land managers on the other hand, more broadly define land use to include the socio-economic purposes and contexts for and within which lands are managed such as subsistence versus commercial agriculture, rented versus owner occupier, or private versus public land. Thus even when land cover appears to be the same, land use change could still be observed using expert knowledge and interviews with land managers to determine which human activities are occurring in different parts of the landscape (Ellis and Pontius, 2007).

This paper focuses on the land use change within the catchments of some major river systems in southern Ghana – Densu Birim, and Ayensu rivers, which are important sources of domestic, agricultural and industrial water for local communities as well as urban centers, including Accra.

The general objective of the study was to find out the causes and impacts of land use change within river catchments on river systems and how these impacts could be curtailed to safeguard river health for the sustainability of river systems.

The study specifically sought to:

- investigate the existing land use types in the Okyeman Traditional Area;
- evaluate local livelihood systems responsible for land use change
- find out factors leading to land change within the study area;
- examine the effects of land use change on river systems; and,
- recommend appropriate interventions and control measures to reduce adverse impacts of land use on river systems.

Data for the study was derived from analysis of remotely sensed LANDSAT 7 ETM satellite image dated 14-02-2000 covering the Okyeman Traditional Area. The service Centre for Remote Sensing and Geographic Information Systems (CERSGIS), located at the Department of Geography and Resource Development of the University of Ghana was employed in the analysis. The outfit produced a detailed land use map on request, which was analyzed in combination with existing historical information to explain the current land use types and how these affect river systems within the catchments.

Data from Y26 questionnaires administered in 33 communities under the Darwin Project in the Okyeman Traditional Area was also analysed and incorporated.

Additional date was derived from the existing literature on land use, land use change, land cover change and related subjects. The data was culled from both published and unpublished sources including scientific journals, books, workshop proceedings and internet sources.

The analysis of the data was mainly through qualitative means involving descriptions, and in-depth explanations.

Results and discussion

Land Use Categories of the study area

The land use map (Fig. 1) shows that 30 different land use classes existed in the area by 14-02-2000 as illustrated in Table. 1. These classes have been summarized into 12 broad categories in Table 2, which also illustrates the percentage of each category to

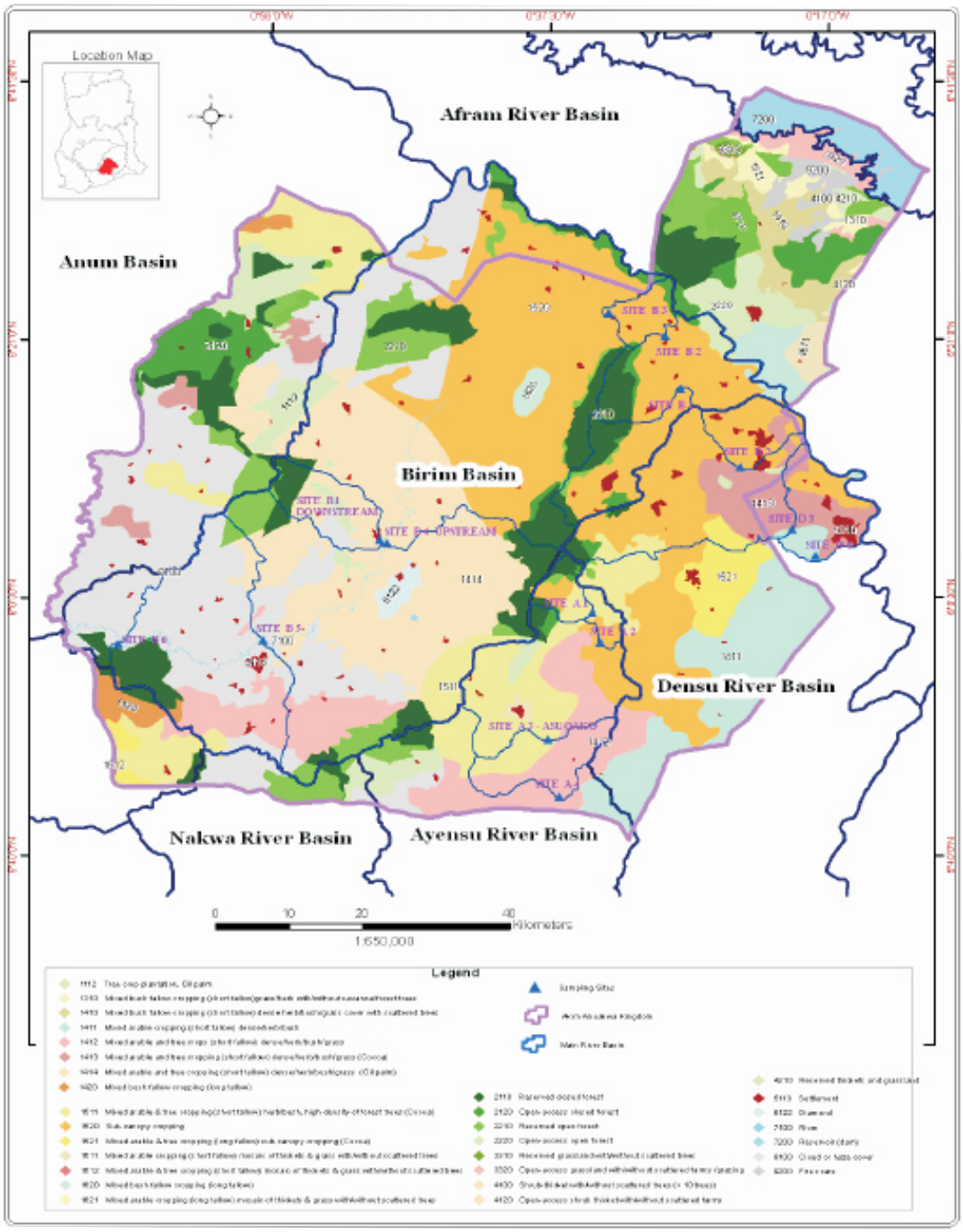

Fig. 1. Land use map of the project area

TABLE 1
Detailed Land Use Classes in the Okyeman Traditional Area

	Land use Class	*Area (ha)*
	Mixed Arable Cropping Category	
1	Mixed arable cropping (short fallow) dense/herb/bush	211560.427
2	Mixed arable & tree cropping (short fallow) mosaic of thickets & grass with/without scattered trees	122047.685
3	Mixed arable and tree crops (short fallow) dense/herb/bush/grass	99168.699
4	Mixed arable cropping (long fallow) mosaic of thickets & grass with/without scattered trees	3640.121
5	Mixed arable cropping (short fallow) mosaic of thickets & grass with/without scattered trees	7153.911
	Open Access Category	
6	Open-access closed forest	53616.706
7	Open-access open forest	30019.058
8	Open-access shrub thicket with/without scattered farms	22622.604
9	Open-access grassland with/without scattered farms /grazing	11809.163
	Mixed Bush Fallow Category	
10	Mixed bush fallow cropping (short fallow) dense herb/bush/grass cover with scattered trees	13502.556
11	Mixed bush fallow cropping (long fallow)	9910.129
12	Mixed bush fallow cropping (short fallow)grass/herb with/without savanna/forest trees	2980.890
13	Mixed bush fallow cropping (long fallow)	2257.933
	Reserved Category	
14	Reserved mosaic of thickets and grassland	5168.162
15	Reserved grassland with/without scattered trees	2027.012
16	Reserved shrub-thicket	9588.986
17	Reserved open forest	37265.658
18	Reserved closed forest	76928.358
	Mixed Arable Tree Cropping Category	
19	Mixed arable and tree cropping (short fallow) dense/herb/bush/grass (Oil palm)	98582.244
20	Mixed arable & tree cropping (short fallow) herb/bush, high density of forest trees (Cocoa)	96380.157
21	Mixed arable and tree cropping (short fallow) dense/herb/bush/grass (Cocoa)	49543.589
22	Tree crop plantation, Oil palm	8528.36
23	Mixed arable & tree cropping (long fallow) sub-canopy cropping (Cocoa)	26151.710
	Others	
24	Shrub-thicket with/without scattered trees (< 10 trees)	107.795
25	Fire scars	6265.408
26	Sub-canopy cropping	171201.362
27	River	4628.038
28	Human settlements	9063.354
29	Mining (Diamond)	2669.479
30	Reservoir (Dam)	82.294
	Total	1194471.84

TABLE 2
Broad Land Use Categories in the Okyeman Traditional Area

	Land use Category	*Area (Ha)*	*% of Total*
1	Mixed Arable Cropping Category	443570.843	37.14
2	Open Access Category	118067.531	9.88
3	Mixed Bush Fallow Category	28651.508	2.4
4	Reserved Forest / thicket / grassland Category	130978.176	10.97
5	Mixed Arable Tree Cropping Category	279186.06	23.37
6	Shrub-thicket with/without scattered trees (< 10 trees)	107.795	0.01
7	Fire scars	6265.408	0.52
8	Sub-canopy cropping	171201.362	14.33
9	River	4628.038	0.39
10	Human settlements	9063.354	0.76
11	Mining (Diamond)	2669.479	0.22
12	Reservoir (Dam excluding the Volta)	82.294	0.01
	Total	1194471.84	100%

Source: Modified from CERSGIS, 2007

the total area. It could be observed again from Table 2 that farming is a dominant activity in the area. Mixed arable cropping, mixed arable tree cropping and sub-canopy cropping categories, together constitute about 74.84% of all land use activities in the area. Areas under some form of protection including forests, thickets and grasslands constitute about 10.97%, which is very significant considering the fact that country wide, about 15% of the total land area has been set aside as forest reserve.

Whereas other categories of land use namely open access areas and mixed bush fallow categories may be of some significance, the most disquieting category is human settlements (0.76%). In fact, expansion of human settlements in the area according to Yorke and Margai (2007), has been quiet phenomenon. Associated with human settlements is human population which has also been on the ascendency since the 1960s. Population figures computed for some major towns in the area showed that from the period 1960 to 2000, the population of Kade and Suhum has increased by 300 % whereas that of Asamankese and Kibi have more or less doubled. The spiral impact of population growth on river systems occurs as a result of proximate drivers like farming, mining operations, indiscriminate waste disposal and livestock grazing (FAO, 1999, Ansah-Asare and Asante, 2000).

Main livelihood systems in the Okyeman Traditional Area

Livelihoods generally refer to "the capabilities, assets (stores, resources, claims

and access) and activities required for a means of living" (Chambers and Conway, 1992, p 7). Land provides the basic means of livelihood enhancement in West Africa (Udo, 1978). It is considered as natural capital that yields products utilized by human populations for their survival (Ellis, 2000). A survey under the Darwin Project of the Okyeman Traditional Area by the socio-economic team in 2007 revealed that farming is the main occupation of inhabitants of the area. Table 3 illustrates the results of analysis. The table shows that fringe communities of ten forest reserves in the area engaged mostly in farming with the percentage of those engaged in the activity ranging from 42% to 91%. This implies that agricultural land use is most widespread, which underscores our earlier assertion using the results of land use map analysis, which showed that 74.84% of the study area is under agriculture. These results support our argument that the driving force of land use change is place-specific and influenced by the nature of rural economy. According to IUCN (2008), from historic times, increases in food production through farmland expansion to meet growing needs have always been at the expense of millions of hectares of forest. This is a real cause for concern since out of the total land area, only 10.97% is under some form of protection and only 10.36% is natural or semi-natural forest, according to analysis of the land use map.

Causes of Land Use Change and its Impact on Densu, Birim and Ayensu River Systems

Population growth and increasing development pressures are rapidly transforming river basins across Sub-Saharan Africa (Yorke and Margai, 2007). In general, vegetation cover within river basins and beyond has often changed as a result of anthropogenic pressures and in recent times, human-induced climate

TABLE 3
Percentage of People Engaged in Farming within Communities Fringing Forest Reserves in the Study Area

Forest Blocks	*Percentage of Fringe community Members Engaged in farming*
Nsuensa	61.29
Atewa	72.36
Apaam	82.75
Norborpong	41.91
Esukawkaw	76.39
Okyemanpaw	54.60
Esuboni	91.89
Southern Scarp	55.71
Bunso Aboretum	58.33
Worobong South	70.00

Source: Darwin Project Survey

change (Guerra *et al*., 1998; Janetos and Justice, 2000).

The Densu Basin

Historical data revealed that the Densu River basin has undergone massive transformation over the last three decades as a result of various land use activities. The dominant land use types in the basin presently are agriculture, urban development, grazing, residential and transportation infrastructure and fishing (Yorke and Margai, 2007). Specific activities under these broad land use types are conversion of lands into croplands leading to deforestation, conversion of tree crop farms into food crop farms, livestock grazing, shifting cultivation, slash-and-burn farming practice and urban sprawl (de Moraes *et al*., 1998, FAO, 1999). Three major land use activities have however been very conspicuous. The first is agricultural intensification. The Densu basin according to Gyasi *et al.* (1994) serves as one of Ghana's most productive agricultural zones, giving rise to a complex mosaic of land cover categories as shown in Fig. 1. Agricultural activities in the area have not only been intensified but also become pervasive to the extent that most of the landscape has been dramatically transformed in the process into a patchwork of land cover classes (Attua, 1996).

The second land use activity is conversion to residential land use to meet the growing needs of human settlements. Fast growing areas with high potentials to impact adversely on the Densu basin include Kasoa, Ablekuma, Gbawe, Adenta, Madina, Abokobi, and Frafraha (Yorke and Margai, 2007) all of which are major suburbs of Accra, or heavily populated areas close to Accra as in the case of Kasoa. The broader Densu basin (including areas outside the Okyeman) is therefore one of the most highly populated river basins in Ghana.

Another dominant land use activity is conversion from cocoa farms to food crop farms to meet urban food demands. Agyepong and Kufogbe (1996) indicated that the system of farming in most parts of the basin has progressively changed from cocoa cultivation to food crop farming over the last two decades. This change has obviously exposed the basin to high mean runoff leading to accelerated erosion and subsequently stream sedimentation.

GIS and remote sensing analysis by Yorke and Margai (2007) confirmed earlier studies that conversion of agricultural land use from tree crop to food crop farming to meet the demands of the burgeoning urban population on one hand, and conversion of farmland into residential lands mainly around major towns and cities on the other, are major driving forces affecting this valuable aquatic resource.

The Birim Basin

Land use activities along the Birim basin that impact the river include farming and mining in and around Akwatia and Kwabeng townships; indiscriminate waste disposal especially in satellite towns like Oda; water extraction and deforestation for fuel wood and other domestic uses; excessive use of chemical fertilizers and land degradation due to improper agricultural practices (Ansah-Asare and Asante, 2000).

Small scale mining in particular has very debilitating effects on the Birim basin. Portions of the basin are littered with water-

filled excavated trenches and marshy areas whose waters are not only turbid but contain pollutants from gold extraction and diamond mining (Ansa-Asare, 1995).

The results of a limno-chemical characterization and water quality assessment of the Birim River carried out by Ansa-Asare and Asante, (2000) indicated that the waters were slightly acidic with pH range of 6.2-6.9. This result again showed that 61.1% of the pH values fell within the natural background level range of 6.5-8.5. The river waters were also well oxygenated due to their turbulence with resultant diffusion action, and had Mean DO (dissolved oxygen) of 7.4 mg L^{-1}, which was 72% above the natural background level range of 5.0-7.0 mg L^{-1}.

The waters of the basin also showed an overall ionic dominance pattern of Ca>Mg and HCO_3>Cl>SO_4, typical of fresh water systems, due to the dominance of Ca and HCO_3. The results further revealed that calcium and magnesium showed a strong linear correlation r = 0.95 significant at P <0.001, which was an indication of strong weathering pattern within the basin (Ansa-Asare and Asante, 2000). The authors explained that the nutrient loads were influenced by domestic, agricultural and industrial activities, as well as biogeo-chemical reactions in the soil. They also noted that the seasonal variations of nutrients were higher in the rainy season than in the dry season.

The results finally pointed to the fact that observed changes in the physical and chemical properties of soil and pollution of surface and ground waters negatively affect the sustainability of agricultural ecosystems as well as the quality of water resources, which in turn have negative feedback on the environment.

As part of the intervention measures to inform the public about the inimical human actions that impact negatively on the Densu, Birim and Ayensu Rivers, the area has attracted very extensive research work (Ansa-Asare, 1995, Attua,. 1996, Abu-Juam *et al.*, 2003, Yorke and Margai, 2007, McCullough, *et al.,* 2007). Most of the research highlighted the pertinent problems and gave useful suggestions. Based on earlier works, the government of Ghana in 2001 placed a ban on all farming activities along the Densu basin (Daily Graphic, Friday, 14/09/2001). The Ghana Forestry Commission has also empowered its Forest Guards to effect arrest of people who engage in illegal activities within the reserves in these catchments. There is also a ban on small scale mining in the entire country. One is however yet to see the full enforcement of some of these regulatory instruments.

The Ayensu Basin

The Ayensu Basin encompasses parts of West Akyem and Agona districts of Ghana. The river has two major tributaries namely River Akora, which flows through the Agona Swedru Township in the Central Region and River Abuchem which drains Asamankese, the West Akyem District Capital. Environmental issues confronting the Ayensu basin within the Okyeman Traditional Area include insanitary conditions such open defecation along river banks, improper location and poor maintenance of dumpsites along river banks, heaping of industrial waste notably saw dust from nearby sawmills along river banks, farming close to river banks and

inappropriate use of agro-chemicals by farmers within the basin (Appau-Attafuah, 2000). Water quality analysis carried in 2000 to determine *p*H, turbidity, conductivity and total dissolved solids, indicated that values recorded at the headwaters of Ayensu River were within the Environmental Protection Agency (EPA), Ghana and World Health Organization (WHO) permissible limits. However values for turbidity, suspended solids and colour in the downstream sites of the river were higher and in some cases above what the EPA and WHO recommended for drinking water. A similar trend was recorded for conductivity and total dissolved solids at the respective sites (Appau-Attafuah, 2000). The downstream sites again had high values for sodium and chloride, higher than levels found in most fresh water bodies in the tropics but within the WHO recommended limits (Appau-Attafuah, 2000).

These findings imply that a combination of various human activities in the upstream of the Ayensu River was impacting negatively on the downstream sites of the river. Considering the fact that a sizable percentage of the people are engaged in agriculture as indicated above and population of the country continue to grow at an annual rate of 2.7% (GSS, 2005), there is an urgent need for policy interventions to reverse the trend since majority of rural folks depend on the river for domestic water supply.

Conclusion

The paper sought to examine the types of land use and their impacts on river systems in the Okyeman Traditional Area, and how these impacts could be reduced to safeguard river health for the sustainability of river systems. Data collected through extensive literature search for Densu and Birim basins together with land use map analysis revealed that several land use classes exist. These include agriculture, forest reserves, bush fallow, mining and residential, among others. Historical accounts revealed that land use types in the area have dramatically changed over the years as a result of anthropogenic pressures including demands on agriculture and residential units, conversion of cocoa farms into food crop farms, fuel wood extraction, indiscriminate waste disposal, excessive use of chemical fertilizers and diamond mining.

The impacts of these human activities in the Okyeman Traditional area have translated into catchment erosion, river sedimentation, surface and ground water pollution, increased turbidity, increased water acidity, increased Mean Dissolved Oxygen and high nutrient loads. Though a lot of efforts have been made by researchers and government alike, to circumvent the situation, little seems to be achieved due to ineffective law enforcement culture.

In conclusion, it is worthwhile to note that existence of multiplicity of land use types within a region is an indication of human pressure on the land resources. Livelihood types like agriculture systems which are based on land resources, and which are affected by underlying drivers like population dynamics tend to alter land use thus, reducing its resilience to external forces like rainfall run-offs. Pressures on land resources through intensification of farming activities and associated misuse of agrochemicals, short fallow and expansion of farming activities into forest areas tend to affect water supply and aquatic fauna, which

are at the receiving end of all these activities. To protect the aquatic fauna and ensure sustainable water supply, there is the need to streamline land use activities, conserve vital ecosystems like watershed areas and maintain buffers along stream channels as a matter of policy.

Recommendations

The contribution of Densu, Ayensu and Birim rivers to rural as well as urban water supply in Ghana cannot be gain said. Anthropogenic forces coupled with natural factors, however, pose major threat to their respective catchments and aquatic resources. In order to circumvent the negative trend, the following recommendations have been made:

1. There is need for educational programmes aimed at sensitizing local community members to good environmental practices to safeguard further land use change and to sustain good ecosystems health. Under this initiative, Agricultural Extension Officers could be empowered to carry out rural outreach programmes through workshops and rural open fora, aimed at educating farmers on conservation agricultural practices like cover cropping, agro-forestry, mulching, contour ploughing, strip cropping and many more.
2. Farmer education is also required to train farmers in the appropriate use of agrochemicals since misuse of such chemicals can be very inimical to water quality and river systems. Training programmes should involve actual field demonstrations by Extension Officers at least periodically before the start of the planting season.
3. District Assemblies and other regulating agencies should make bold attempts to enforce environmental regulations at the local level. For instance, the proposed Local Government Act that prohibits development activities including farming within 50 meters off river basins should be enforced at the local level to protect river bank erosion.
4. Finally, the national agenda to reduce poverty in the country through the Ghana Poverty Reduction Programme needs to be vigorously pursued to provide jobs for the teaming local populations in order to reduce overdependence on land as the only means of livelihood enhancement.

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