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Review

Land use change and sediment yield studies in Ghana: Review

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Understanding the factors and processes controlling catchment sediment yield is crucial and fundamental to water resources management and development. This review provides an inventory on land use and sediment yield studies in Ghana and explores their existing link. The review through desktop studies analyzed the discussions and related studies on the impact of land use/cover change on sediment yield. Available literature showed that generally sediment yield is sensitive to land use/cover, however, the evidence of the empirical link between land use/cover and the catchment sediment yield is unclear. Though various land use/cover and sediment yield studies have contributed to the understanding of the variations in catchment erosion rate resulting from land use/cover changes, the results do not show strong influence of cover types on sediment yield. The results relate sediment yield to rainfall, runoff and catchment area without exploring the empirical evidence of land use impact. Thus, empirically, the extent to which sediment yield varies with land use /cover changes still remain unclear. Further research is recommended to ascertain the empirical link between land use/cover change and catchment sediment yield.

Key words: Sediment yield, river basin, land use/cover changes, water resources management.

INTRODUCTION

Amongst the issues threatening water security both in quantity and quality in Ghana is the increasing rate of river basin's sediment yield, transport and deposition (Eswaran et al., 2001). Sediment yield is the mass of sediment annually leaving a catchment per unit area (Verstraeten and Poesen, 2001). It is the results of erosion and deposition processes within a catchment. Sediment yield and transport has been noted for altering the hydrological regimes of river basins (Ayivor and Gordon, 2012). High sediment yield usually comes with elevated soil loss within catchment, which compromises soil productivity affecting water quality and quantity as

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well as flood and control fishing, in addition to reducing reservoir lifespan and modifying river channel morphology (Mensah, 2009; Kusimi, 2008b; Peng et al., 2008). Thus, reliable information on the expected sediment yield of river basins is important for water resources management and development (Kusimi et al., 2014; Akrasi, 2011).

The sediment yield of a catchment result from the multiplicative effects of land use, climate, basin's size, geology and topography (Inca, 2009; Morehead et al., 2003; Milliman et al., 1999). The relative importance and sensitivity of these factors in explaining the spatial variation in sediment yield is crucial. Hence, the physical mechanisms responsible for the variation in sediment loads must be explained in order to have proper understanding of the interaction between sediment yield and these related factors responsible for the variability in sediment load. This is fundamental in addressing the hydrological challenges of river basins in order to predict the potential impact of existing practices and trends.

The influence of land use/cover on the sediment yield of a catchment is acknowledged by both land use and sediment researchers. Land use refers to the utilization of land for economic or productive use (IPCC, 2001) whilst land cover refers to the biophysical status of the earth's surface and immediate sub-surface (Campbell, 2002). The status of land use/cover determines the influence of rainfall intensity on erosion rate, transport and deposition (Costa et al., 2003). Therefore, changes in land use patterns automatically determine the variations in the catchment sediment yield. Hence, it is important to understand clearly the relative importance of land use/cover changes in explaining the spatial variation in sediment yield. The available evidence regarding the impact of conversion of land use type to another on the sediment loads of rivers must however, be explored. The aim of this study is to review and provide inventory on land use and sediment yield studies in Ghana and to explore their empirical relationship. This will help enhance the understanding of the link between land use, erosion and sediment yield in Ghana, which is fundamental to the development of sustainable land use alternatives as an integral component of river basin and water resources management.

LAND USE AND LAND COVER STUDIES IN GHANA

Land use and land cover studies are important in water resources development and management as it directly affect the hydrological processes of river basin's (Costa et al., 2003; Fohrer, 2001). Accurate knowledge of existing land use and cover practices and trends represent the foundation for water resources management (Kelarestaghi and Jeloudar, 2011).

Land use has been defined by IPCC (2001) and IGBP/IHDP (1993) as the utilization of land for economic or productive use. Hence, land use is based on function, the purpose for which the land is being used or the entire range of direct management activities that affect the nature of the land (Aduah et al., 2015; Campbell, 2002) such as agricultural, forestry, industry, as others related. On the other hand, land cover refers to the biophysical status of the earth's surface and immediate sub-surface (Briassoulis, 2006; FAO, 1997) including vegetation, human constructions, water, etc. It must be emphasized that land cover is the visual result of land use at a certain moment in time whilst land use reflects the degree of human activities directly related to land and making use of its resources.

While the earth's land mass remains essentially static with time and space, human demands have changed and increased, impacting heavily on the land as well as its flora and fauna composition in various ways (Ndulue et al., 2015). Consequently, the land use and cover characteristics are being changed from time to time. The conversion or alteration of the natural landscape or changes in structure and function (quantitative) and changes in the areal extent (qualitative) of a given type of land use or cover refers to land use and land cover (LULC) change (Seto et al., 2002; Briassoulis, 2006). Thus, land cover change has a unique signature on the topography and soil distribution, that gives rise to changes in natural resource.

The first land use map of Ghana using remote sensing was completed in 1998, at a scale of 1: 250,000 under the Ghana Environmental Resource Management Programme (GERMP) (Amatekpor, 1999). Since then there have been several applications of remote sensing in land use studies (Table 1). Some are published in refereed journals whilst others are unpublished masters' and PhD theses from universities across the globe. Generally, land use and land cover studies have been focused on land use/cover change assessment and prediction (Basommi et al., 2015), land use and climate (Dale, 1997), land use and water resources (Ayivor and Gordon, 2012), land use and soil erosion and sediment (Kavian et al., 2014), drivers of land use change (Braimoh and Vlek, 2005).

Over the year's various land use and land cover studies in Ghana, using different methods and techniques have shown obvious occurrence of land use and land cover changes. Results of studies within the tropical forest zones shows consistent decline of forest lands (Forkuo and Adubofour, 2012) whilst those within the savanna belt shows conversion from savanna lands to urban and farm lands (Adusei, 2014). For example, the review of historical document by FAO (2015) showed that between 1975 and 2000, agricultural lands expanded from 13 to 28% and increased rapidly to 32% of Ghana's total land area in 2013. The changing status of the forest area towards farmlands, urban lands and mining areas has been reported in several land use and land cover studies carried out in different areas for different periods (Table 1). Besides, there has been the conversion of different

Table 1. List of Land use and Land cover (LULC) data sources and Mapping in Ghana.

Research type	Spatial coverage	Data sources	Temporal coverage	References
LULCC	Owabi Catchment	LandSat & ASTER	1986 & 2007	Forkuo and Adubofour (2012)
LULCC	Prestea-Huni-Valley District	LandSat, ALOS & OrthoPhotographs	1990, 2000, 2010, & 2010	Perprah (2015)
LULCC	Barekese catchment	LandSat	1973,1986 & 2000	Boakye et al. (2008)
LULCC	Tarkwa Mining Area	LandSat & ASTER	1986, 2002 & 1990, 2007	Kumi-Boateng et al. (2012)
LULCC	Wassa-West District	LandSat	1986, 2002	Kusimi (2008a)
LULCC	Ejisu-Juabeng	LandSat	1986 & 2004	Asubonteng, 2007
LULCC	Weija Catchment	LandSat	1990,2000 & 2011	Antwi-Agyakwa (2014)
LULCC	Nadowli District	LandSat	1990, 2000 & 2014	Basommi and Guan (2015)
LULCC	Wa East District	LandSat	1991, 2000 & 2014	Basommi et al. (2015)
LULCC	Birim North	LandSat	2002,2008 & 2015	Mayeem (2016)
LULCC	Densu Basin	LandSat & ASTER DEM	1990 & 2000	Yorke and Margai (2012)
Land use	Okyeman Traditional Area	LandSat	2000	Ayivor and Gordon (2012)
LUC(Agric)	Akwapim South District	LandSat & Aerial Photos	1985, 1991 & 1972, 1974	Allotey (2000)
LULCC	Volta Basin of Ghana	LandSat	1984, 1992 & 1999	Braimoh and Vlek (2004)
LCC(Urban)	Tema Metropolitant Area	LandSat	19990,2000 & 2007	Amenyo-Xa et al. (2010, unpublished)
LULC	Bawku Municipality	LandSat	1989 & 2009	Adusei (2014)
LULC(Urban)	New Juabeng Municipality	LandSat	1985 & 2003	Attua and Fisher (2011)
LULC(Urban)	Accra	LandSat/GPS Survey	1985 & 2010	Yeboah et al. (2017)
LULCC	Lake Bosomtwe Basin	LandSat	1986, 2002 & 2008	Adjei et al. (2014)
LULCC	Southern Ghana	LandSat	2000 & 2010	Coulter et al. (2015)
LULCC	Ankobra River Basin	LandSat ALOS-AVNIR-2	1986, 1991 & 2002, 2011	Aduah et al. (2015)
LULC	Mampong Municipality	LandSat	1991, 2001 & 2009	Frimpong (2015)
LULCC	Ejisu-Juabeng	LandSat	1986 & 2007	Amoah et al. (2012)
LULC	Sekondi-Takoradi Metropolis	LandSat, Topomap & River discharges	1988 & 2008	Aduah and Baffoe (2013)
LULCC	Bosomtwe District	LandSat	1986, 2010 & 2014	Appiah et al. (2015)

LULCC: Land use and land cover change.

classes of land use and land cover classes with different rates and magnitudes.

LAND USE AND LAND COVER CLASSIFICATION

Land use/cover classification is the process of mapping that is based on either visual or computer aided analysis to categorize all land cover features by their relative spectral patterns or unique similarities (Foody, 2002). Many classification systems are being used throughout the world including the world land use classification, the Canada land inventory and land use classification, the second land use survey of Britain classification and Canadian land use classification (Scace, 1981). Even though there is not an internationally accepted format, most land use and cover studies especially in Ghana appears to be modelled based on the classification scheme of Anderson et al. (1976) (Table 2).

The application of remote sensing (RS) and geographic information system (GIS) over the years has greatly enhanced image processing and classification for the production of thematic maps. It provides a map-like representation of the earth's surface that is spatially continuous and highly consistent, as well as available at a range of spatial and temporal scales (Foody, 2002). As a result, research on land use and land cover have demonstrated the full functionality of RS and GIS in (i) classifying past and present land uses (Boakye et al., 2008), (ii) predicting future changes (Amoah et al., 2012), (iii) evaluating the magnitude and rate at which these changes are occurring (Peprah, 2015), and (iv) spatially characterizing the patterns of change, pinpointing locations at risk (Yorke and Margai, 2012). This is made possible through the use of remote sensing imageries such as Landsat images (MSS,TM, ETM, ETM$^+$), Systeme Probatoire D'observation de la Terre-High Resolution Visible Image (SPOT-HRV), IKONOS, Moderate-resolution Imaging Spectroradiometer (MODIS), Sentinel, QUICKbird, Advanced Very High Resolution Radiometer-National Oceanic and Atmospheric Administration (AVHRR-NOAA), Light Detection and Ranging (RADAR), GOES, ASTER, Advanced Land Observation Satellites (ALOS), European Remote Sensing Satellite (ERS-1&2), Japanese Earth Resources Satellite (JERS), Meteosat, Scanning Multi-Channel microwave Radiometer(SMMR), Special Sensor Microwave/Imager (SSM/I), etc. Among these imageries LandSat, ALOS, AVHRR-NOAA, SPOT and ASTER have been identified for land cover/land use and vegetation studies. However, review of land cover studies in Ghana shows most researchers prefers LandSat imageries (Braimoh and Vlek, 2004; Yeboah et al., 2017; Aduah et al., 2015; Boakye et al., 2008) due to the uniqueness of the dataset as the only long-term digital archive with a medium spatial resolution and relatively consistent spectral and radiometric resolution (Yang e t al., 2000). It is also easily accessible and can be obtained at low cost.

Images are classified using either the supervised or unsupervised classification technique or sometimes both. The unsupervised classification uses cluster algorithms to automatically classify an image into several spectral classes based on statistical information within the image. The Cluster algorithms iteratively partition the image spectrally by determining statistical groups based on the numerical information (DN values) present in the image. However, supervised classification aims at allocating features based on their spectral peculiarity to a set of pre-defined classes. This method requires familiarity with the study area through field work, aerial photographs, conventional maps or google earth (Chuvieco and Huete, 2010; Jensen, 2005). Supervised classification systems can be grouped as either parametric or non-parametric methods. The parametric methods include maximum likelihood classification (MLC) (Campbell, 2002), fuzzy-set classifiers (Stavrakoudis et al., 2011), sub-pixel classifiers, spectral mixture analysis (Nichol et al., 2010) and object-oriented classifiers (Platt and Rapoza, 2008). The non-parametric methods include artificial neural networks (ANN) (Laurin et al., 2013; Atkinson et al., 2000), decision tree and support vector machines (Huang et al., 2002). However, available literature indicate that the statistically-based MLC algorithm classification is most preferred and used very often (Yeboah et al., 2017; Forkuo and Adubofour, 2012; Boakye et al., 2008; Kusimi, 2008a).

To assess the correctness of the classification, accuracy assessment is essentially performed in land use and land cover classification (Foody, 2002). Campbell (2002) defined accuracy in thematic mapping from remotely sensed data as the degree of 'correctness' of a map or classification. A map may be considered accurate if it provides an unbiased representation of the region it portrays. In other words, classification accuracy is the degree to which the derived image agrees with the reality or conforms to the truth (Smits et al., 1999). There are many methods of accuracy assessment in literature but the most widely used is the Error (Confusion) matrix though few challenges have been pointed out by Foody (2002). The confusion matrix provides a basic information of the proportion correctly classified (PCC). It may be useful in refining estimates of the areal extent of classes and also enhance the value of classification for the user (Foody, 2002). It also furnishes the analyst with errors of omission and commission as well as overall, user and producer accuracy (Lillesand and Kiefer, 1999). Most of the literatures reviewed in this study recorded an overall accuracy of 75% and above signifying strong agreement of the classified image and the reality (Yeboah et al., 2017; Peprah, 2015; Adjei et al., 2014; Forkuo and Adubofour, 2012).

An important tool in monitoring land use and land cover change is the change detection (Mertens and Lambin, 2000). Land use and land cover change detection is the process of identifying differences in the state of land features or phenomenon by mapping it at different times over a period (Coppin et al., 2004; IGBP/IHDP, 1993). It involves the use of multi-temporal datasets to identify areas of change between specific dates of imaging. Copping et al. (2004) categorized remote sensing techniques used for change detection as algebraic, transformation, classification and visual analysis techniques. Algebraic based technique include normalized difference vegetation index (NDVI) differencing, image differencing, image regression and change vector analysis (CVA), the transformation method includes multi-date Principal Component Analysis (PCA), Chi-square transformations and Kauth-Thomas (KT); the classification methods consist of post-classification comparison (PCC), multi-date classification, spectral-temporal combined analysis while visual analysis techniques is primarily based on the visual interpretation of aerial photographs and high resolution images. Algebraic and transformation methods are suitable for detecting continuous changes,

Table 2. Land use/cover classification scheme (Anderson et al., 1976).

Land cover	Description
Water	Water courses (streams, rivers), ponds/flooded, lakes, reservoir
Farms/Shrubs	Short tree species and non-tree, Vegetation such as herbs, grasses and farms, commercial and horticulture crops
Evergreen (deep) forest	Tall trees including indigenous species and mature rubber located mostly in forest reserves and plantation farms
Secondary (Open) forest	Degraded/re-growth forest and tree crops and rubber with open canopy
Settlement	Urban areas, Villages, Paved/Unpaved roads, bare land, car parks, playing fields
Mining areas	Areas where open cast/surface Mining has taken place and mining infrastructures

while classification methods are effective for categorical changes (Abuelgasim et al., 1999), but depend on the accurate geometric registration and classification of individual images. Continuous changes mean changes in the concentration or amount of an attribute (e.g. biomass and the leaf area index of a forest), while categorical changes are the conversion of one land cover type to another (e.g. forest to urban area). The reviewed literature indicates that the classification method, specifically the post-classification comparison is commonly used in the land use/cover change analysis, perhaps because of its effectiveness in categorical changes (Aduah et al., 2015; Kumi-Boateng et al., 2012). However, a good change detection method should indicate the area and rate of change, spatial distribution of changed features, change trajectories of cover types and accuracy assessment of change detection results (Inca, 2009). Change detection has numerous advantages in land use planning. Amongst them includes (i) the provision of the basis for coordinated policies and strategies to guide development at the local level and within the framework of implementing short-term actions, (ii) the revelation of the spatial pattern of development in the area whether negative or positive and thereby helping to identify areas where a particular type of change should be encouraged or discouraged (Lamber et al., 2001).

DRIVING FORCES OF LAND USE AND LAND COVER CHANGES

Land use and land cover changes do not occur in vacuum. It is the resultant effect of human activities within the natural environment. Thence, land use/cover changes are determined by complex interactions of environmental and socioeconomic factors (Kelarestaghi and Jeloudar, 2011). The environmental factors include climate, geomorphology, soil and geology. According to IGBP (1993), possible socio-economic forces behind land use/cover changes can be grouped into six namely population, level of affluence, technology, political structures, attitudes and values of the people. They further argue that land cover modification is mostly driven by human influence rather than natural changes (Ayivor and Gordon, 2012). This is supported by Benneh and Agyepong (1990) that population increase, development policies, urbanization and agriculture contributes greatly to land cover change. Again, some researchers within the country have shown that the rate of land cover changes are the direct results of population, urbanization and agriculture (Appiah et al., 2014; Boakye et al., 2008; Braimoh and Vlek, 2005) which are regional in nature as events in one location impact on land use in other locations (McCusker and Carr, 2006; DeHart and Soule, 2000). However, Lambin et al. (2001) opine that the utilization of new lands was created by local as well as national markets and policies. Therefore, the driving forces are not only regional or global in scale, but also local (Lambin, 2001) in that actions at the local level directly affect land use/cover. Of course the combined application of the various land use theories such as Malthusian and Boserupian that relate land use to population growth, the Ricardian paradigm that links land use to intrinsic land quality, and the Von Thu¨nen paradigm that associates land use to location of land parcels (Mortimore, 1993) indicates that the driving forces are not only regional but also local. Hence, it is imperative for land use/cover researchers to dig deep down to the local level to identify specific factors influencing land use/cover change, be it global, regional or local.

SEDIMENT YIELD OF RIVER BASINS

Sediment yield and loading of river basins present important measure of the hydrology of the drainage basin and the erosion processes (Walling, 1999). Sediments are particles that can be transported by a fluid flow and deposited as a layer of solid particles on the bed of a body of water. Sediment yield of a catchment is the amount of sediment load passing through the outlet of a drainage basin within a specified period of time (Jain et al., 2010; Verstraeten and Poesen, 2001). It involves bed load and suspended load expressed in terms of mass or volume per unit of time. Bed load sediments are those that are transported by saltation and traction e.g. gravels and cobbles whilst suspended load is sediment in suspension by the upward components of turbulent currents (Akrasi, 2011; Nagle, 2000) e.g. silt, clay, and sand. The amount of sediment transported downstream depends on the rate and magnitude of erosion and transporting capacity of the flowing medium, viz: soil erodibility, rainfall erosivity, catchment topography, size and vegetative cover (Ndulue et al., 2015; Pelletier, 2012). Soil erodibility is defined by Hudson (1995) as the soil's susceptibility to erosion which varies with the soil texture, aggregate stability and shear strength apart from soil infiltrability and organic in addition to chemical content. The rainfall erosivity also defines the potential ability of rain to cause erosion. It is based on the kinetic energy and momentum of the runoff. Therefore, the erosivity index of the storm is a function of rain droplet distribution, frequency, intensity and velocity. Oduro-Afriyie (1996) used the Fournier index to estimate the rainfall erosivity indices for stations in Ghana. His results showed that the erosivity index, c for Ghana ranges between 24.5 mm in Sunyani and 180.9 mm in Axim. Small flows carry small sediment loads and are essentially ineffective in scour and deposition.

Topographic features that influence erosion are slope; its size and length as well as shape of a watershed and aspect of a mountain. The amount of erosion on an arable land is influenced by the steepness, length and curvature. Thus, the steeper and longer the slope, the more the erosion (Amegashie et al., 2011). Vegetative cover serves as the protective layer or buffer between the atmosphere and the soil. It interferes with the amount of rain drops reaching the soil surface. The vegetative cover depending on the canopy will protect the soil from the erosive activity of rainfall that is very high (Akrasi, 2008).

SEDIMENT YIELD ASSESSMENT AND MODELING

Soil erosion in river basins continues to be a serious problem in the world (Eswaran et al., 2001). Accurate determination of suspended sediment loads and its associated fluxes in rivers is of great importance for water resources development and management.

There are two approaches for determining the sediment loads in rivers; direct (field) measurement and modeling (physical and empirical). Field measurement methods usually include measurement of suspended sediment load and discharges (Kusimi, 2008b; Akrasi, 2005; Amisigo and Akrasi, 1997), measurement of total eroded sediments and deposited sediment in small catchments and measurement of sediment volumes in ponds, lakes or reservoirs (Amegashie et al., 2011; Adwubi et al., 2009). Measurement of suspended sediment concentration involves sampling and laboratory analysis. Four main types of suspended samplers are available: integrating samplers, instantaneous samplers, pumping samplers and sedimentation traps. The preferred one is the integrating samplers. However, in the absence of depth integrated sampler some researchers such as Akrasi and Ansa-Asare (2008) and Kusimi et al. (2014) used the dipping method and applied the necessary correction according to Rooseboom and Annandale (1981) and Demmak (1976). The sampled water was taken to laboratory to determine the suspended sediment concentration through either the evaporation or filtration method. For high concentrations of sediment, the evaporation method is better whilst the filtration method works better for low concentrations of the water-sediment mixture (Ayibotele and Tuffour-Darko, 1979). Another possibility is to make measurement with a field turbidity meter that has been calibrated against natural samples from the site where its being used (Mawuli and Amisigo 2017; Minella et al., 2008). The suspended sediment concentration obtained can be used to compute for the sediment load in tons per day as well as the specific sediment yield (Akrasi, 2008; Kusimi et al., 2014)

As a result of the difficulties associated with obtaining continuous records of concentration through the direct method due to cost, remoteness of site, number of sampling and technical difficulties (Edwards and Glyssen, 1999) water researchers have resorted to the use of empirical models to estimate the suspended loads in rivers that have no direct measurement (Akrasi, 2011; Akrasi and Ansa-Asare, 2008; Syvitski and Milliman, 2007; Amisigo and Akrasi, 1997). These include the erosion rate method, catchment based method, rating curve method and regression method. For instance, in 1974, Ayibotele and Tuffour-Darko established sediment rating curves for suspended and bedloads for the Densu River at Manhyia, Amisigo and Akrasi (2000) also developed sediment yield prediction model for south-western river basins in Ghana, Akrasi (2005) developed the same for the Volta basin system, while Akrasi and Ansa-Asare (2008) developed prediction model for Pra river basin using runoff and catchment area. Later, Akrasi (2011) developed simple empirical models using multiple regression to predict suspended sediment yield within the south-western and coastal river basis systems in Ghana. The models relate the sediment yield to the catchment area and simple climatological indices such as rainfall and runoff. However, sometimes the results obtained from the curve may be problematic since storm flow hydrographs usually, but not always, are characterized by higher suspended sediment concentrations during the rising limb than the falling limb. For instance, Kusimi (2008b) noticed from his study in the Densu river basin that even during low flows, sediment concentration remains relatively high.

Besides, there are various empirical models to estimate the sediment yield of catchment such as the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978), Modified Universal Soil Loss Equation (MUSLE) (Blaszczynski, 2003) and the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997). The USLE/RUSLE is a field scale model and cannot be used to estimate the sediment yield directly. This is because it does not account for sediment deposition along the travelling path. To account for this Sediment Delivery Ratio (SDR) is incorporated to estimate the total sediment transported to the basin’s outlet (Jain and Kothyari, 2000). However, USLE/RUSLE only predict the amount of soil loss through the sheet and rill erosions but not from gully, channel or bank erosion which may lead to underestimation. Notwithstanding, the RUSLE and its integration with GIS and remote sensing has been widely used by many researchers to display the spatial distribution of soil erosion and estimate the annual soil loss of a catchment with good results (Ayalew, 2014; Kayet et al., 2018). The uncertainties that normally stem from the availability of long-term reliable data for soil erosion modelling are not unique to RUSLE application. The model is relatively simple, easy to parameterize and requires less data to operate with.

There are also physically-based models developed for hydrologic prediction and for understanding hydrologic processes which are very useful in environmental management. Particular models developed to explore the impact of land use change on hydrological processes includes Soil and Water Assessment Tool (SWAT) (Arnold et al., 1998), Water Evaluation Prediction Project (WEPP) (Nearing et al., 1989), European Soil Erosion Model (EUROSEM) (Morgan et al., 1998), Areal Nonpoint Source Watershed Environment Response Simulation (ANSWERS) (Beasley et al., 1980), Chemicals, Runoff and Erosion from Agricultural Management Systems (CREAMS) (Kinsel, 1980), Systeme Hydrologique Europian-TRANsport (SHETRAN) (Ewen et al., 2000), Kinematic Runoff and Erosion model (KINEROS) (Woolhiser et al., 1990), etc. These are event based models, continuous, spatially and temporally distributed at catchment scale. However, these models require huge amount of data inputs, and many calibration parameters, that are characterized by complex laboratory analyses or difficult and expensive field data collection (Silva et al., 2010). Hence, their application in developing countries where physical sediment data are virtually non-existent is highly limited.

SEDIMENT YIELD STUDIES IN GHANA

Even though sediment yield measurement in Ghana is deficient due to high cost and technical challenges, a number of studies have been conducted. Literature shows that between 1974 and 1976, Water Resources Research Institute (WRRI) measured bed load at eight different gauging stations on some of the large rivers (basin >2000 km^2) in southern Ghana (Ayibotele and Tuffour-Darko, 1979). Also, sediment loads of rivers in the south-western river basin systems of Ghana were measured (Amisigo and Akrasi, 2000). Table 3 gives an overview of current collected sediment yield data in Ghana and their sources. It must be noted from Table 3 that the sediment yield measurement from gauging stations (GS) are generally suspended load and do not include the bed load. This perhaps explains the differences between the sediment yield derived from reservoir sedimentation rate and gauging stations. Nonetheless, the difference may also be attributed to specific catchment characteristics and environmental conditions. For example, sediment observation from reservoirs are mainly for small catchment (<5 km^2), while that from gauging stations are for relatively larger catchment (>100 km^2). It shows small catchment generate more sediment because it has steeper gradient, less storage capacity, relatively shorter travel distance and less time for entrapment, and greater response to flood (Milliman et al., 1999).

Available literature also indicate that water researchers have developed predictive models to estimate sediment yield for rivers where no measurement is conducted. For example, Akrasi developed simple predictive tool from measured sediment data to estimate the total suspended sediment input to the Volta Lake. His results showed annual suspended sediment input of about 52 tkm^{-2}year^{-1} from the catchment surface (Akrasi, 2005). Also, Akrasi and Ansa-Asare used collected data within the Pra basin to develop simple empirical model to predict specific suspended sediment yield and nutrient export coefficients within the Pra basin. The sediment yield of Pra basin was estimated to be 50.8 tkm^{-2}year^{-1} (Akrasi and Ansa-Asare, 2008). Akrasi (2011) used measured suspended sediment transport for 21 monitoring stations in southern Ghana to develop simple predictive models for catchment where no measurement had been undertaken. The model results showed that the sediment yield of the south-western and coastal basins ranged between 11 and 50 tkm^{-2}year^{-1} (Akrasi, 2011). The model indicated that runoff and catchment areas account for a large proportion of the variance of the suspended sediment yield.

SEDIMENT YIELD AND LAND USE/COVER CHANGE

Land use and cover features plays significant role in the erosion and sedimentation process of a catchment. They control the intensity of the rain drops reaching the soil surface causing erosion, and the frequency of the overland flow and sediment deposition (Mitchel, 1990; Bryan and Campbell, 1986). Hence, some land use and vegetative types create favorable conditions for runoff and sediment loss than others (Nunes et al., 2011). For instance, conversion of agricultural, forest, grass, and

Table 3. Sediment yield data and sources in Ghana.

River/Catchment name	Measuring location	A (km^2)	Sediment yield ($tkm^{-2}year^{-1}$)	Type	Reference
-	Dua	0.35	10270	R	Adwubi et al. (2009)
-	Kumpalgogo	0.40	1699	R	Adwubi et al. (2009)
-	Doba	0.70	1850	R	Adwubi et al. (2009)
-	Zebilla	1.1	2668	R	Adwubi et al. (2009)
Annum	Konongo	681	17.9	GS	Akrasi and Ansa-Asare (2008)
Birim	Bunso	150	24.3	GS	Akrasi and Ansa-Asare (2008)
Oda	Anwiankwanta	1303	26.9	GS	Akrasi and Ansa-Asare (2008)
Offin	Mfensi	1515	24.8	GS	Akrasi and Ansa-Asare (2008)
Birim	Oda	3248	40	GS	Akrasi and Ansa-Asare (2008)
Offin	Dunkwa	8345	45.1	GS	Akrasi and Ansa-Asare (2008)
Pra	Assin-Praso	9793	32.6	GS	Akrasi and Ansa-Asare (2008)
Pra	Twifu Praso	20767	44.1	GS	Akrasi and Ansa-Asare (2008)
Pra	Beposo	22818	46.9	GS	Akrasi and Ansa-Asare (2008)
Afram	Aframso	308	14.8	GS	Akrasi (2005)
Pru	Pruso	1121	9.1	GS	Akrasi (2005)
Daka	Ekumdipe	6586	26.9	GS	Akrasi (2005)
Oti	Saboba	54890	46.6	GS	Akrasi (2005)
White Volta	Pwalugu	57397	21.7	GS	Akrasi (2005)
Black Volta	Lawra	90658	15.2	GS	Akrasi (2005)
White Volta	Nawuni	96957	22.9	GS	Akrasi (2005)
Black Volta	Bamboi	128759	25.7	GS	Akrasi (2005)
-	Bugri	2.2	1828	R	Amegashie et al. (2011)
Ayensu	Near outlet	1700	88.2	GS	Milliman and Fansworth (2011)
Ankobra	Near outlet	6200	290.3	GS	Milliman and Fansworth (2011)
Pra	Near outlet	38000	63.2	GS	Milliman and Fansworth (2011)
Volta	Near outlet	400000	47.2	GS	Milliman and Fansworth (2011)
Bia	-	10135	25.5	GS	Akrasi (2011)
Tano	-	16061	24.14	GS	Akrasi (2011)
Ankobra	-	8366	48.15	GS	Akrasi (2011)
Butre	-	422	35.34	GS	Akrasi (2011)
Pra	-	23168	49.17	GS	Akrasi (2011)
Amisah	-	1298	27.49	GS	Akrasi (2011)
Nakwa	-	1409	35.85	GS	Akrasi (2011)
Ayensu	-	1709	16.75	GS	Akrasi (2011)
Tordzie	-	2916	11.01	GS	Akrasi (2011)
Oda	Anwiankwanta	1288	51	GS	Kusimi et al. (2014)

Table 3. cont'd

Offin	Adiembra	3101	37	GS	Kusimi et al. (2014)
Birim	Oda	3104	94	GS	Kusimi et al. (2014)
Pra	Brenase	2168	69	GS	Kusimi et al. (2014)
Pra	Assin-Praso	9235	24	GS	Kusimi et al. (2014)
Pra	Twifu-Praso	20625	128	GS	Kusimi et al. (2014)
Pra	Heman	22758	329	GS	Kusimi et al. (2014)

'R' indicates that the sediment yield value was obtained from bathymetric surveys in a reservoir. 'GS' indicates that the value was obtained from measurements at a gauging station.

wetlands to urban areas usually comes with increase in impervious surface, which alter the natural hydrologic conditions such as runoff and sedimentation processes within a watershed. It therefore means that the sediment yield of a basin becomes more sensitive to variations in rainfall intensity and topography as the vegetative cover decreases from forest cover through agricultural crops to rangeland (Vanmaercke et al., 2014; Gellis et al., 2006; Trimble, 1995; Dunne, 1979; Wilson, 1973).

Rivers where sediment yield have both increased and decreased in recent decade resulting from changes in land use have been reported by several researchers in Africa and beyond (Kusimi, 2008b). Asante-Sasu (2016) showed that two years after the construction of Bui dam in Ghana, the gross sediment yield of the reservoir had increase by 41.5% over the designed figure resulting from land use activities. Ngo et al. (2015) concluded that the increase of agricultural land, expansion of urban area and the removal of forest land dramatically increased runoff and sediment of Da River Basin of Hoa Binh province. Again, Huang and Lo (2015) applied SWAT model to assess the impact of land use change on soil and water losses from Yang Ming Shan National Park in Northern Taiwan. Their results showed that 6.9% decrease in forest and 9.5% increase in agricultural land caused sediment yield increase of 0.25 tha^{-1}. Thus, Land use change has generally been accepted as influencing factor contributing to the variation in sediment yield of river basins (Ngo et al., 2015; Tang et al., 2005; Dunne, 1979; Douglas, 1967). However, the evidence for the impact of changing land use on the sediment yield of rivers is still less clear. The empirical relation linking sediment yield to land use features remains unclear. Developed empirical models for the estimation and prediction of sediment yield in river basins in Ghana do not reflect clearly the influence of changes in land use on the sediment yield. Rather, they relate catchment sediment yield to climatological indices: rainfall and runoff, and catchment area only (Amegashie et al., 2011; Akrasi and Ansa-Asare, 2008; Akrasi, 2005). Hence, the contention that land use is the dominant factor to sediment yield of river basins (Kusimi, 2008b; Walling, 1999) and that the influence of other factors becomes more pronounce in a changing land use has been cataloged thoroughly in literatures but without supporting data. Their results and models relate sediment yield to rainfall, runoff and catchment size more than vegetative cover (Amegashie et al., 2011; Akrasi, 2005).

CONCLUSION

Sediment yield of river basins poses great threat to the available water resources. It is generally accepted that sediment yield of a basin is influenced by the effect of land use/cover, rainfall and catchment geomorphology. Various land uses and sediment yield studies discuss the sensitivity of catchment sediment yield to land use change. However, the relative importance of land use/cover type in explaining the spatial variation in sediment yield is less clear-cut. Existing sediment studies and regression model results especially in Ghana relate sediment yield of studied catchment to rainfall, runoff and catchment morphology without exploring empirical evidence of land use impact. Though the observed variations in sediment yield have been strongly attributed to land use/cover changes, the results do not show strong influence of cover types on sediment yield. For sustainable water resources management, it is important to empirically explore the link between land use change and the sediment yield of river basins. The study also recommends the use of the RUSLE model to display the spatial distribution of soil erosion for data-deficient basins since it does not require huge amount of data for calibration and validation.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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