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Mapping the Environmental and Economic Cost of Soil Loss on the Resiliency of Abia State Hydrological Basin: A study between 1972 and 2015

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A R T I C l E I N F O

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A B S T R A C T

Soil erosion is one of the major environmental issues which has caused considerable economic damage and still remains an intractable problem in many parts of Abia state. InVEST model was used to map the environmental and economic cost of soil loss by studying: (1.) sediment exported and retained from soil loss, (2.) nutrient exported and retained from soil loss, and (3.) the resiliency of the hydrological basin to withstand changes from soil and nutrient loss using GIS (Geographic Information System)technique. Estimated total soil loss from sediment export was found to have a higher significant impact on the hydrological basin of Abia state than sediment retained. The model estimated nutrient (Phosphorous and Nitrogen) exported and retained against the economic benefit of nutrient exported and retained as well as the economic value of the basin for retaining nutrient over the specified time span. This found nutrient and economic value lost from sediment export higher than sediment retained. A resilient check was performed on the Abia state basin to ascertain the strength, ability of the basin to spring back into shape and withstand the pressure from on/off-site damage accumulated from soil loss, nutrient loss, and nutrient economic value lost. Abia state basin was found to have a resilient level of 69.20% low and 30.80% high in 1972, 19.63% of very low and 88.88% of low resilient in 1986 and 2003, while in 2015 very low resilient of 39.30% and 60.70% of low resilient. The result reveals a drastic reduction in the resilient level between 1972 and 2015 as well as its agro-productivity, socio economic equalities and overall well-being of Abia sate. This research highlights the fact that proper conservation measures needs to be applied to improve agro productivity, water quality standard and the general well-being of Abia state.

Introduction

Soil erosion by water is a major problem in the world (Lant et al., 2015), with economic, social and environmental implications arising from both on-site and off-site effects (Engel et al., 2008). Soil erosion damages capital that supports economic development and improvements in quality of life. Human-induced conversion of natural capital reduces future service flows, unless the capital is restored when degraded (Blignaut et al., 2007). According to Herath (2001), the losses of soil in terms of the irreplaceable inputs are the primary factors determining the productivity and economic costs of erosion. The causes and consequences of soil erosion are far from being settled. Inappropriate government policies and institutions, commodity prices, farm subsidies, taxes and other forms of government intervention have all being implicated in soil erosion.

Lipton (1987) argued that high commodity prices would encourage “soil mining” for quick and bigger crops now. LaFrance (1992) concludes that where both cultivation intensity and the level of conservation activity responds to market forces, higher prices lead to more intensive use of soil thereby aggravating soil erosion. Clarke (1992) found that investment on soil conservation measures would increase when product prices are favorable and that economically viable conservation technologies are available. World Bank’s world development report (1986) states that the poor performance of agriculture in low-income countries is due to macroeconomic policies such as overvalued exchange rates and agricultural taxes which alter incentives for farmers. Chisholm et al.(1997) examined Sri Lanka’s trade liberalization and cautioned that economic losses from soil erosion in Sri Lanka are quite substantial even under low erosion-low economic impact assumptions and that trade reforms alone are inadequate to substantially reduce soil erosion. They contend that policies, which directly target soil erosion, are required to minimize social losses from such erosion.

Understanding the economic costs of soil erosion is vital for farmers, soil conservation experts and policy makers in order to put the potential benefits of soil conservation practices into context (Shiferaw et al., 2005), and to set priorities for land management practices (Igwe & Fukuoka, 2010; Kidane & Alemu ,2015). Soil erosion produces both on-site and off-site damage such as water pollution and sedimentation of waterways (Herath, 1985). Some off-site effects can be beneficial but often damaging effects are apparent. These externalities persist due to market failure caused by the absence of property rights. The costs of soil erosion and the benefits of soil conservation are difficult to determine.

However, erosion and sedimentation are natural processes that contribute to healthy ecosystems, but too much may have severe consequences. Excessive erosion can reduce agricultural productivity, increase flooding and pollutant transport, and threaten bridges, railroads and power infrastructures. Erosion can lead to sediment build-up, which strains water infrastructures, such as reservoirs and flood control systems, and increases water treatment costs. Sedimentation is particularly problematic for reservoirs, which are designed to retain sediment as water is released (Tallis et al., 2013). Regular sediment removal can avoid some of these issues but this involves expensive maintenance costs. The magnitude of sediment transport in a watershed is determined by several factors. Natural variation in soil properties, precipitation patterns, and slope create patterns of erosion and sediment runoff. Vegetation holds soil in place and captures sediment moving overland. However, changes in land management practices can alter the sediment retention capacity of land by removing important vegetation (Tallis et al., 2013). To reduce the damages and costs associated with sedimentation, land, water and reservoir managers require information regarding the extent to which different parts of a landscape contribute to sediment retention, and how land use changes may affect this retention. InVEST model aims to provide these kinds of information. The outputs from these models will allow planners and managers to consider how LULC (Land Use/Land Cover) change in one area in the basin can cause sedimentation problems at other locations. Also, the model provides information for non-point source pollutants and deal with nutrient pollutants (nitrogen and phosphorous) lost and retention. For the development of policy, oriented towards sustainable development of agriculture, quantitative assessment of the on-site and off-site damage due to erosion was performed.

Material and Method

This research is interested in estimating the cost of soil erosion (on/off-site damage) using InVest model adopting GIS (Geographic Information System) technique. The on-site costs were estimated on the basis of soil and nutrients loss. Offsite costs were estimated using sedimentation. Data collected for this study include: (1.) Field survey, this entails taking GPS reading and ground trotting of study locations; (2.) USGS (U.S. Geological Survey) 90m SRTM (Shuttle Radar Topography Mission) DEM (Digital Elevation Model); (3.) Acquired analogue base maps of administrative and soil map (contenting the soil texture and organic material content and root restricting layer depth) obtained from Ministry of Lands, Survey and Urban Planning, Town planning department, Umuahia, Abia state; (4.) Landsat Multispectral Scanner (MSS) for 1972, Thematic Mapper (TM) 4 for 1986, Enhanced Thematic Mapper Plus (ETM+) 7 for 2003 and Operational Land Imager (OLI) 8 for 2015 imagery from USGS Earth Explorer with a Path/Row of

191/055,056 and a resolution of 30m; and (5.) Meteorological variables such as Rainfall were acquired from National Root Crop Research Institute (NRCRI), Umudike between 1972 and 2015 (a span of 43 years). NRCRI is located between 5° 29^1 North to 7° 33^1 East on an elevation high of 122m in Abia state. Also, current and relevant literatures were reviewed for Abia state with regards to the subject matter. The study extent covers Abia state and is located east of Imo state and shares common boundaries with Anambra, Enugu and Ebonyi states to the North West, North and North East respectively (Nwilo et al., 2011). To the East and South East, it is bounded by Cross River and Akwa Ibom states and by Rivers state to the South. It occupies a landmass of 5,833.77 square kilometers. Abia state is located on longitude 7° 09^1 to 8° 05^1 East and latitude 4° 48^1 to 6° 03^1 North (Figure1). Abia state comprises of seventeen (17) Local Government Areas (LGAs). The state is divided into four hydrological basins which include: (1.) Imo river basin; (2.) Cross river basin; (3.) Enyong creek sub basin; and (4.) Ikwa Ibo river basin (Figure 1).

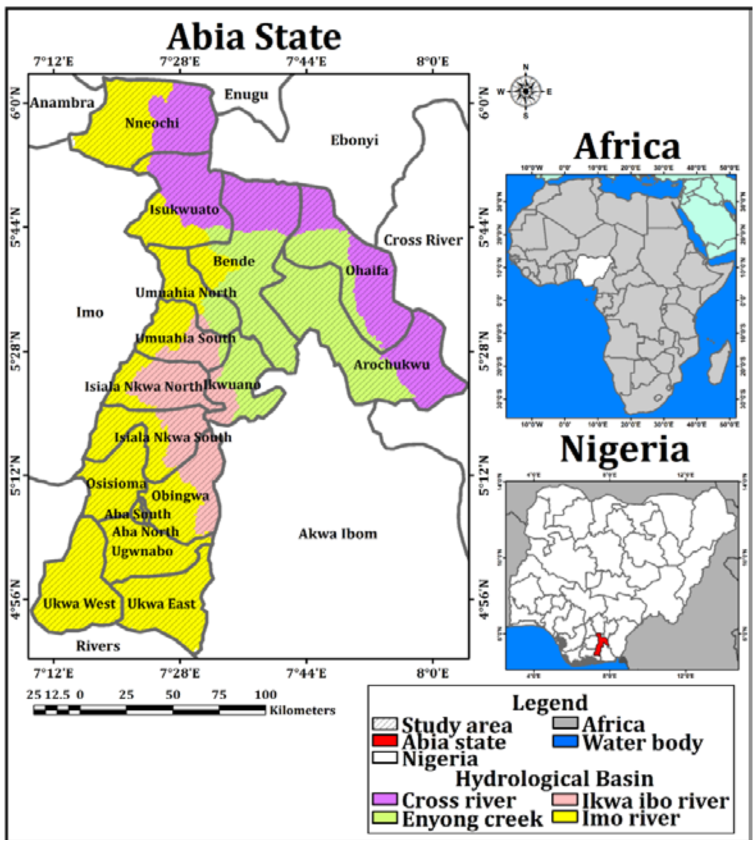

Figure 1. Location of Abia state.

Acquired analogue base maps were scanned and converted to digital/raster images. The scanned maps were georeferenced and projected to UTM 32N and digitized in ArcGIS 10 software. Also, attribute tables and values was created and used to carrying out the necessary GIS analysis/manipulation and operations with a view to produce relevant maps, reports, charts and tables. Bands 4, 5 and 7 of the acquired Landsat MSS for 1972, TM 4 for 1986, ETM+ 7 2003 and OLI 8 for 2015 with a resolution of 30m were selected, mosaic and enhanced. Supervised classification method were adopted to define training sites, extract signatures and classify the remotely sensed imagery using maximum likelihood classification procedure into six classes, namely: *Agriculture land, bare ground, primary forest, secondary forest, built-up area, wetland and water body,* this was implemented using Idrisi Selva software. ArcGIS10 Arc Hydro extension was used to perform drainage analysis on a terrain model. The output was used to generate Abia state basin which was used as input *Sediment Retention* and *Nutrient Retention* modeling.

In this study, *Sediment Retention model* was used to calculate the average annual soil loss from each parcel of land, determining how much of that soil may arrive at a particular point of interest, estimating the ability of each parcel to retain sediment, and assessing the cost of removing the accumulated sediment on an annual basis, the model uses the Universal Soil Loss Equation (USLE) (Wischmeier & Smith, 1978) at the pixel scale, which integrates information on LULC and soil, as well as a digital elevation model and rainfall. Universal Soil Loss Equation (**USLE**) provides the foundation of the biophysical step of the InVEST sediment retention model (version 2.6, a toolset of ArcGIS 10 software):

$$USLE = R\ L\ S\ K\ C\ P \quad \textbf{(1.)}$$

Where, ***R*** is the rainfall erosivity, ***K*** is the soil erodibility factor, ***LS*** is the slope length-gradient factor, ***C*** is the crop-management factor and ***P*** is the support practice factor.

Rainfall erosivity index (**R**) (required). **R** is a GIS raster dataset, with an erosivity index value for each cell. This variable depends on the intensity and duration of rainfall in the area of interest. The following equation is widely used to calculate the ***R Index***:

$$R=E.I30= (210+89\log_{10}I30)*I30 \quad \textbf{(2.)}$$

Where, *E*= Kinetic energy of rainfall expressed in metric MJ * m/ha/cm of rainfall and *I30*= Maximum intensity of rain in 30 minutes expressed in cm per hour. Rainfall erosivity index value for each output cell is given as MJ*mm*$(ha*h*yr)^{-1}$.

Soil map was used in deriving the Soil erodibility (***K)*** factor. Texture is the principal factor affecting ***K*** (Soil erodibility**)**, but soil profile, organic matter and permeability also contribute. ***K*** is sometimes found as part of standard soil data maps, or can be calculated from soil properties. The following equation can be used to calculate ***K*** (Roose, 1996):

$$K = 27.66 \times m^{1.14} \times 10^{-8} \times (12 - a) \div (0.0043 \times (b - 2) \div (0.003 \times (c - 3) \quad \textbf{(3.)}$$

Where, ***K*** = Soil erodibility factor (t*ha/MJ*mm); *m* = (silt (%) + very fine sand (%))(100-clay (%)); *a* = Organic matter (%); *b* = Structure code: (1) Very structured or particulate, (2) Fairly structured, (3) slightly structured and (4) Solid; *c* = Profile permeability code: (1) rapid, (2) moderate to rapid, (3) moderate, (4) moderate to slow, (5) slow and (6) very slow. Value for different soil types are also, found in Tallis et al.(2013).

Appropriate ***P*** and ***C*** factor were added to the land use/ land cover class and stored as tables in the attribute table as biophysical table. The support practice factor, ***P***, accounts for the effects of contour plowing, strip-cropping or terracing relative to straight-row farming up and down the slope. The cover-management factor, ***C***, accounts for the specified crop and management relative to tilled continuous fallow. ***C*** factor for Abia state was obtained from the LULC for 1972, 1986, 2003 and 2015 based on existing literature (Roose, 1977). The support practice (***P***) has a value between 0 and 1 for each land use in Abia state. Ground trotting was carried out to confirm that there were no measurable conservation measures in Abia state.

The slope threshold that the model uses to switch between the following two equations is specified as a model input and depends on the local geomorphology and basin characteristics. *For low slopes:*

$$LS\left(\frac{flowacc.cellsize}{22.13}\right)^{nn}\left(\left(\frac{\sin(slope.0.01745)}{0.09}\right)^{1.4}\right)\times 1.6 \quad \textbf{(4.)}$$

$$nn = \begin{cases} 0.5, slope \geq 5\% \\ 0.4, 3.5 < slope < 5\% \\ 0.3, 1 < slope \leq 3.5\% \\ 0.2, slope \leq 1\% \end{cases} \quad \textbf{(5.)}$$

Where, *flowacc* = Accumulated water flow to each cell and *cellsize* = Pixel size or the grid resolution (10m, 30m, 90m, etc.). *For high slopes:* We use the following equation, defined by Huang and Lu (1993) for areas with slopes higher than the threshold identified by the user:

$$LS = 0.08\lambda^{0.35} prct\_slope^{1.6} \quad \textbf{(6.)}$$

$$\lambda = \begin{cases} cellsize, flowdir = 1,4,16, or 64 \\ 1.4.cellsize, other\ flowdir \end{cases} \quad \textbf{(7.)}$$

Where, *prct_slope* = Pixel's percent slope and *flowdir* = Flow direction of the pixel. This research estimates the ability of vegetation to keep soil in place on a given pixel by comparing erosion rates on that pixel to what erosion rates would be on that pixel with no vegetation present (bare soil). The bare soil estimate is calculated as follows:

$$RKLS = R \times K \times LS \quad \textbf{(8.)}$$

Erosion from the pixel with existing vegetation is calculated by the *USLE* equation:

$$USLE = R \times K \times LS \times C \times P \quad \textbf{(9.)}$$

Avoided erosion (sediment retention) on the pixel is then calculated by subtracting *USLE* from RKLS. The potential soil loss was classified based on the results gotten from *USLE* (***R L S K C P***) computation above using table 1. Avoided erosion (sediment retention) on the pixel is then calculated by subtracting USLE from RKLS. Vegetation does not only keep sediment from eroding where it grows. It also traps sediment that has eroded upstream. The USLE equation overlooks this component of sediment dynamics, so we attempt to account for it as follows. All soil that the USLE equation estimated is eroded routed downstream via a flow path (Tallis et al., 2013). However, sediment eroded is trapped by downstream vegetation thereby retaining sediment. The model also determines the total sediment load exported that reaches the stream from each pixel on the landscape (Tallis et al., 2013). The total retained sediment ($sret_x$) is equal to the sum of the sediment removed by the pixel itself and the sediment removed through routing filtration (Tallis et al., 2013). The model provides the option to consider two services associated with the retention of sediments on the landscape; improved water quality and avoided sedimentation of reservoirs (Tallis et al., 2013). We assume that each pixel on the landscape gets an equal proportion of this allowance in the following calculation:

$$sed\_ret\_wq_x = sret_x - \frac{wq\_annload}{contrib} \quad \textbf{(10.)}$$

Where, $sret_x$ = Total retained sediment calculated above; *wq_annload* = Annual allowed sediment load; and *contrib* = Number of pixels in the watershed (Tallis et al., 2013). The model outputs includes: *(1.) Total potential soil loss per basin (in tons/basin, not /ha); (2.) Total amount of sediment exported (in tons/basin, not /ha); (3.) Total sediment retained within each basin; and (4.) total sediment export within each basin (in tons/basin, not /ha).*

The InVEST *Water Purification Nutrient Retention model* (version 2.6, a toolset of ArcGIS 10 software) was used to calculate the amount of nutrient retained on every pixel then sums and averages nutrient export and retention per basin. The pixel-scale calculations allow us to represent the heterogeneity of key driving factors in water yield such as soil type, precipitation, vegetation type, etc (Tallis et al.,2013). The model used Reckhow et al. (1980) export coefficients and annual averages of pollutant fluxes derived from various field studies that measure export from parcels this was done using the following equation:

$$ALV_x = HSS_x \times pol_x \quad \textbf{(11.)}$$

Where, ALV_x = Adjusted loading value at pixel *x*; pol_x = Export coefficient at pixel *x*; and HSS_x = Hydrologic sensitivity score at pixel *x* which is calculated as:

$$HSS_x = \frac{\lambda_x}{\overline{\lambda}_W} \quad \textbf{(12.)}$$

Where, λ_x= Runoff is index at pixel x, calculated using the following equation, and $\bar{\lambda}_W$= the mean runoff index in the watershed of interest.

$$\lambda_u = \log\left(\sum_u Y_u\right) \quad \textbf{(13.)}$$

Where, $\sum_u Y_u$= Sum of the water yield of pixels along the flow path above pixel *x* (it also includes the water yield of pixel *x*). The model helps us model how much pollutant leaving each pixel and determine how much of that load that is retained by each downstream pixel, as surface runoff moves the pollutant toward the stream (Tallis et al., 2013).

To calculate the amount of service delivered, the model decreases retention by the amount of 'allowed' pollution in the water body of interest, if an allowed amount is given (Tallis et al., 2013). If a threshold is given, the service level is calculated in biophysical terms as follows:

$$net_x = retained_x - \frac{thresh}{contrib} \quad \textbf{(14.)}$$

Where, $retained_x$ = Amount of retention calculated; *thresh* = Total allowed annual load for the pollutant of interest; and *contrib* = Number of pixels on the landscape. Pixel values are then summed or averaged to the basin scale.

The nutrient retained is determined, for each basin based on the avoided treatment costs that retention by natural vegetation and soil provides (Tallis et al., 2013). We make this calculation as follows:

$$wp\_Value_x = Cost(p) * retained_x * \sum_{t=0}^{T-1} \frac{1}{(1+r)^t} \quad \textbf{(15.)}$$

Where, wp_Value_x = Value of retention for watershed *x*; *Cost (p)* = Annual treatment cost in \$(currency)/kg for the pollutant of interest (*p*), *retained$_x$* = Total pollutant retained by sub watershed, *x*; *t* = time span being considered for the net present value of water treatment; and *r* = Discount rate used for calculating the net present value (Tallis et al., 2013).The watershed values are then summed to the basin to determine the water purification value per basin. The results are presented on a basin scale. Two nutrient output is of interest in this research which includes: (a.) phosphorous and (b.) nitrogen. The model output presented includes: *(1.) Total amount of nutrient exported (in kg/basin, not /ha); (2.) Total amount of nutrient retained by each basin* representing the environmental service of water purification*, (in kg/basin, not /ha); and (3.) the economic benefit (per basin) of filtration by vegetation delivered at the downstream point(s) of interest over the specified time -span (in USD, $ /time span).*

Hydrological basin resilient check was performed on Abia state hydrological basin to ascertain strength, ability of the basin and capacity to spring back into shape or withstand the pressure from on/off-site damage accumulated from soil loss. The following components were used as indicator to measure the resilient of the hydrological basin: potential soil loss, sediment export (yield), nutrient and economic value exported. A value of 1 to 5 was assigned to the components in table 1. The assigned values are sum then divided by number of component or sample size, expressed mathematically as:

$$RC = \frac{C_1 + C_2 + C_3 + ...C_n}{N} \qquad \textbf{(16.)}$$

Where, *RC*= Resilient check; $C_{1...n}$= Components (such as soil loss, sediment exported.); *N*= Sample size. Based on the above, the output known as the *resilient level* ranges between values 1 to 5; this is assigned the following new class, namely: (1.) *Very low*, (2.) *Low*, (3.) *Moderate*, (4.) *High* and (5.) *Very high resilient*.

Table 1. Potential Soil loss, Sediment export, Nutrient and Economic value loss.

Tolerance Class	Potential Soil Loss *	Sediment Export**	Nutrient Loss (%)	Economic Value Loss (%)
Very low	<7	<2	10 -30	10 -30
Low	7.00-12.00	2.00- 5.00	30 - 50	30 - 50
Moderate	12.00-25.00	5.00-15.00	50 - 60	50 - 60
High	25.00-37.00	15.00-25.00	60 - 80	60 - 80
Severe	> 37.00	> 25	80 - 100	80 - 100

Source: Stone (2006) as cited by Lanuza (2001)*; Johnson and Gembhart (1982)**

Results and Discussion

Mapping the effect of Sediment Exported and Retained from Soil Loss on Abia state Hydrological Basin

Effect of Soil Erosion on Abia state Hydrological Basin

To study soil erosion, *Sediment Retention model* was used to map potential soil loss areas in Abia state as shown in figure 2 for 1972, 1986, 2003 and 2015. In Abia state, minimum, maximum and mean soil erosion was estimated for 1972, 1986, 2003 and 2015 as presented in figure 3 for Abia state hydrological basin. A minimum soil loss of 15.78 tons/basin, 33.10 tons/basin, 15.53 tons/basin, and 19.36 tons/basin for 1972, 1986, 2003 and 2015 for Imo river basin was recorded. Ikwa Ibo river basin recorded a minimum soil loss of 55.65 tons/basin, 15.38 tons/basin, 15.53 tons/basin, and 19.62 tons/basin for 1972, 1986, 2003 and 2015. Enyong Creek sub basin recorded a minimum soil loss of 55.65 tons/basin, 32.87 tons/basin, 14.09 tons/basin and 7.54 tons/basin for 1972, 1986, 2003 and 2015. Cross river basin recorded a minimum soil loss of 1.79tons/basin, 0.00 tons/basin, 0.01 tons/basin and 0.00 tons/basin for 1972, 1986, 2003 and 2015. A maximum soil loss of 56.62 tons/basin, 46.85 tons/basin, 65.47tons/basin and 70.74tons/basin for 1972, 1986, 2003 and 2015 for Imo river basin was recorded. Ikwa Ibo river basin recorded a maximum soil loss of 56.52tons/basin, 15.38tons/basin, 41.89 tons/basin and 70.74 tons/basin for 1972, 1986, 2003 and 2015. Enyong creek sub basin recorded a maximum soil loss of 63.54 tons/basin, 32.87 tons/basin, 41.89tons/basin and 70.74 tons/basin for 1972, 1986, 2003 and 2015. Cross river basin recorded a maximum soil loss of 63.54tons/basin, 56.26tons/basin, 65.47 tons/basin and 70.74 tons/basin for 1972, 1986, 2003 and 2015. A mean soil loss of 49.13 tons/basin, 34.90 tons/basin, 39.69 tons/basin and 64.00 tons/basin for 1972, 1986, 2003 and 2015 for Imo river basin was recorded. Ikwa Ibo river basin recorded a mean soil loss of 55.99 tons/basin, 15.38 tons/basin, 15.54 tons/basin and 19.65 tons/basin for 1972, 1986, 2003 and 2015.

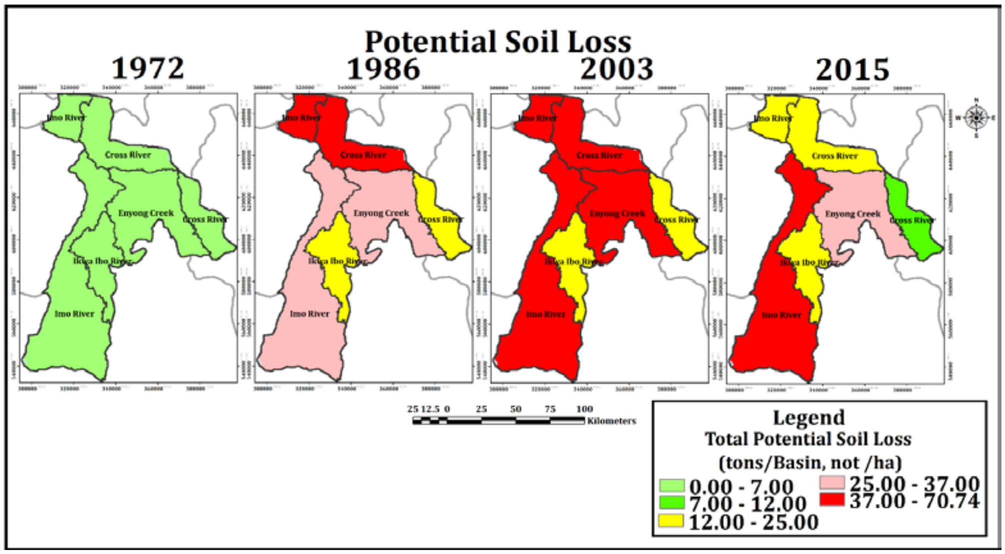

Figure 2. Potential soil loss for Abia state in 1972, 1986, 2003 and 2015.

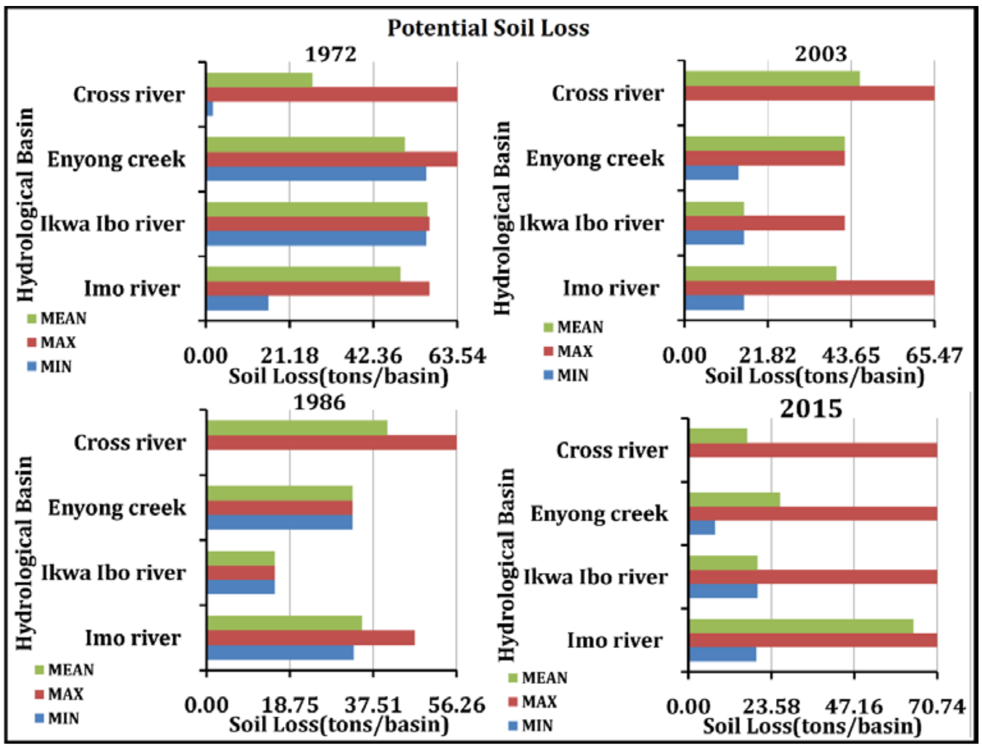

Figure 3. Minimum, maximum and mean potential soil loss for Abia state hydrological basin in 1972, 1986, 2003 and 2015.

Enyong creek sub basin recorded a mean soil loss of 50.26 tons/basin, 32.87tons/basin, 41.88tons/basin and 26.08 tons/basin for 1972, 1986, 2003 and 2015. Cross river basin recorded a mean soil loss of 26.95 tons/basin, 40.69 tons/basin, 45.88 tons/basin and 16.72 tons/basin for 1972, 1986, 2003 and 2015. Based on factors that influence soil erosion in Abia state, land areas covered by forest area are protected and experience relatively little soil erosion because raindrop and wind energy are dissipated by the biomass layer and the topsoil is held by the biomass (Agriculture California, 2002; SWAG, 2002). In forest areas, a minimum of 60% forest cover is necessary to prevent serious soil erosion (Singh & Kaur, 1989; Haigh et al., 1995; Forest Conservation Act, 2002) but in Abia state it ranges from 6 to 36%

with a soil loss of 218.70tons/basin to 86,822.68 tons/basin.

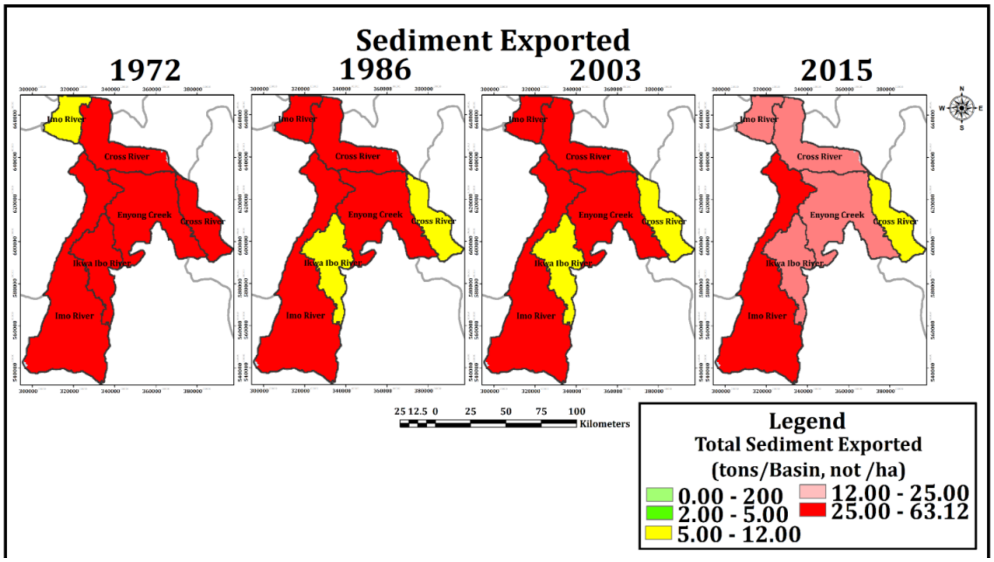

Figure 4. Sediment exported for Abia state in 1972, 1986, 2003 and 2015.

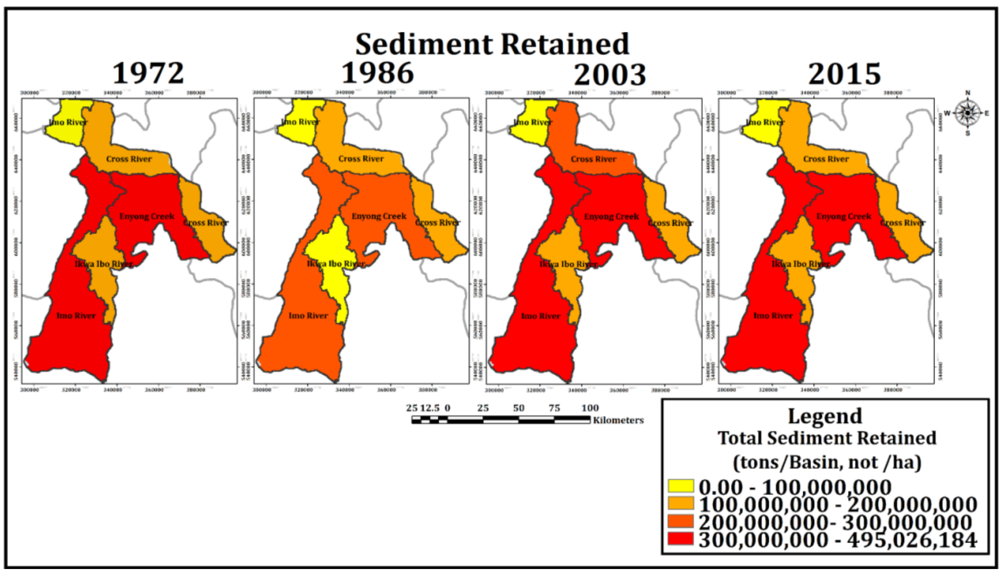

Figure 5. Sediment retained for Abia state in 1972, 1986, 2003 and 2015.

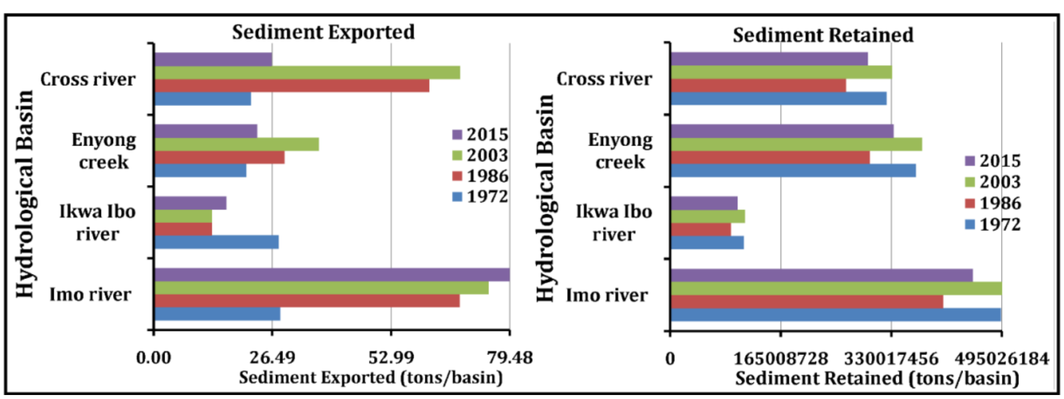

Figure 6. Sediment exported and retained in Abia state hydrological basin for 1972, 1986, 2003 and 2015.

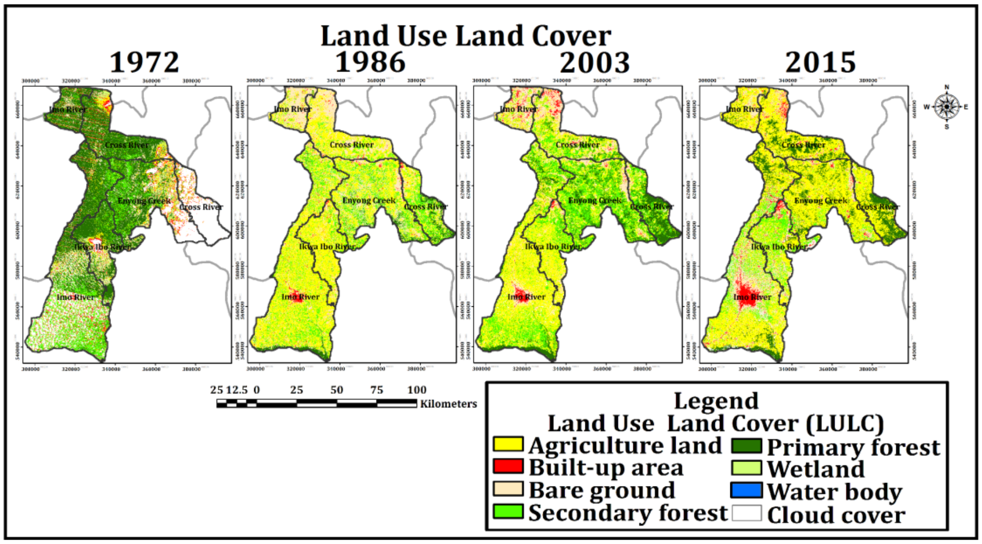

Figure 6. Land use land cover of Abia state for 1972, 1986, 2003 and 2015.

The extensive removal of forests for crops is followed by extensive soil erosion between 15.78 tons/basin to 56.52 tons/basin for 1972, 5.38 tons/basin to 56.52tons/basin for 1986, 0.01 tons/basin to 65.47 tons/basin for 2003 and 0.00 tons/basin to 70.74 tons/basin for 2015. This reveals that Imo basin has a higher amount of sediment being exported then, followed by Cross river basin, Ikwa Ibo river basin and Enyong creek sub-basin between 1972 and 2013. In conclusion, high amount of sediments are eroded and transported in the hydrological basin of Abia state.

Mapping the effect of Nutrient Export, Retention and Economic value from Soil Loss on Abia state Hydrological Basin

Effects of Nutrient Export and Retention on Abia state Hydrological Basin

Based on sediment exported and retained, nutrient export and retention was computed for Abia state hydrological basin and presented in figure 9, 10, 12 and 13. Total amount of nitrogen and phosphorous exported to the stream basin, and the total amount of nitrogen and phosphorous retained by the landscape in each hydrological basin for either dredging or water quality is shown in figure 11 and 14. In Abia state, eroded soil carry away vital plant nutrients, figure 9 shows the map of nitrogen exported and figure 11 shows the graphical details of the distribution of nitrogen exported in Abia state hydrological basin for 1972, 1986, 2003 and 2015. Total nitrogen of 34328 kg/basin in 1972, 170820 kg/basin in 1986, 142825 kg/basin in 2003 and 294944 kg/basin in 2015 for Imo river basin was exported. For Ikwa Ibo river basin, total nitrogen of 10378.5 kg/basin in 1972, 33798 kg/basin in 1986, 26329.80 kg/basin in 2003 and 51645 kg/basin in 2015 was exported. For Enyong creek sub basin, total nitrogen of 16258.30 kg/basin in 1972, 115847kg/basin in 1986, 117377kg/basin in 2003 and 46501.30 kg/basin in 2015 was exported.

Figure 10 shows the map of nitrogen retained and figure 11 shows the graphical detail of the distribution of nitrogen retained in Abia state hydrological basin for 1972, 1986, 2003 and 2015. Total nitrogen of 23551.20kg/basin in 1972, 48844.20kg/basin in 1986, 84270.50 kg/basin in 2003 and 100540.00kg/basin in 2015 was retained for Imo river basin. For Ikwa Ibo river basin, 6172.31 kg/basin in 1972, 12923.00 kg/basin in 1986, 10633.50 kg/basin in 2003 and 28945.40kg/basin in 2015 were retained for nitrogen. For Enyong creek sub basin, total nitrogen of 15920.30kg/basin in 1972, 122754.70 kg/basin in 1986, 21078.00 kg/basin in 2003 and 28405.50kg/basin in 2015 was retained. For Cross river basin, total nitrogen of 10727.30 kg/basin in 1972, 30363.80 kg/basin in 1986, 40502.80 kg/basin in 2003 and 20896.20 kg/basin in 2015 of nitrogen was retained.

Figure 12 shows the map of phosphorous exported and Figure 14 shows the graphical details of the distribution of phosphorous exported in Abia state hydrological basin for 1972, 1986, 2003 and 2015. Total phosphorous of 12398.30 kg/basin in 1972, 46970.3 kg/basin in 1986, 38255.2 in 2003 and 75646.4 kg/basin in 2015 for Imo river basin was exported. For Ikwa Ibo river basin, total phosphorous of 2711.83 kg/basin in 1972, 9476.83kg/basin in 1986, 7378.98 kg/basin in 2003 and 13469.8kg/basin in 2015 was exported. For Enyong creek sub basin; total phosphorous of 5747.68kg/basin in 1972, 33661.6 kg/basin in 1986, 32031.5 kg/basin in 2003 and 18709.7 kg/basin in 2015 was exported. For Cross river basin, total phosphorous of 5779.82 kg/basin in 1972, 11994.8 kg/basin in 1986, 11214.9 kg/basin in 2003 and 12313.8 kg/basin in 2015 was exported.

Figure 13 shows the map of phosphorous retained and figure 14 shows the graphical details of the distribution of phosphorous retained in Abia state hydrological basin for 1972, 1986, 2003 and 2015. Total phosphorous of 41555.40kg/basin in 1972, 13514.60kg/basin in 1986, 23402.00kg/basin in 2003 and 27838.40kg/basin in 2015 was retained for Imo river basin. For Ikwa Ibo river basin, total phosphorous of 8408.91kg/basin in 1972, 3584.08kg/basin in 1986, 3147.89kg/basin in 2003 and 7938.67 kg/basin in 2015 was retained. In Enyong creek sub basin, total phosphorous of 21706.50kg/basin in 1972, 6311.25 kg/basin in 1986, 6168.00kg/basin in 2003 and 7521.79kg/basin in 2015 was retained. While for Cross river basin, total phosphorous of 20500.10kg/basin in 1972, 8771.67 kg/basin in 1986, 11564.70 kg/basin in 2003 and 5667.05 kg/basin in 2015. The result reveals that eroded soil contains about 3 times more nutrients than the remaining soil left. Furthermore, it was found that phosphorus is apparently the most deficient plant nutrient eroded in the soil than nitrogen in Abia state hydrological basin. A total estimate of 22.00% to 40.69% of the soils nutrient is retained and 88% to 59.31% are loss for nitrogen and 22.34% to 37.96% for phosphorous is retained while 77.66% to 62.04% is loss between 1972 and 2015. This affects water quality, plant growth and overall agro-productivity. A deficit in soil nutrient between 1972 and 2015 with phosphorous leading the way by 62.04% against 59.31% of nitrogen was observed in Abia state hydrological basin. This accounts for 1% of the sediment discharged as export by the landscape against the 99% retained in Abia state. The exported sediment however small still has an impact on Abia state hydrological basin, based on this; the effects LULC change on nutrient loss was studied.

Effect of Land use change on Nutrient Export in Abia state Hydrological Basin

Based on the Land Use Land Cover (LU/LC) change analysis for each hydrological basin in Abia state presented in figure 7 nutrient exported and retained were examined for 1972, 1986, 2003 and 2015. Figure 15 shows the graphical details of the distribution of nitrogen exported in Abia state hydrological basin for 1972, 1986, 2003 and 2015.

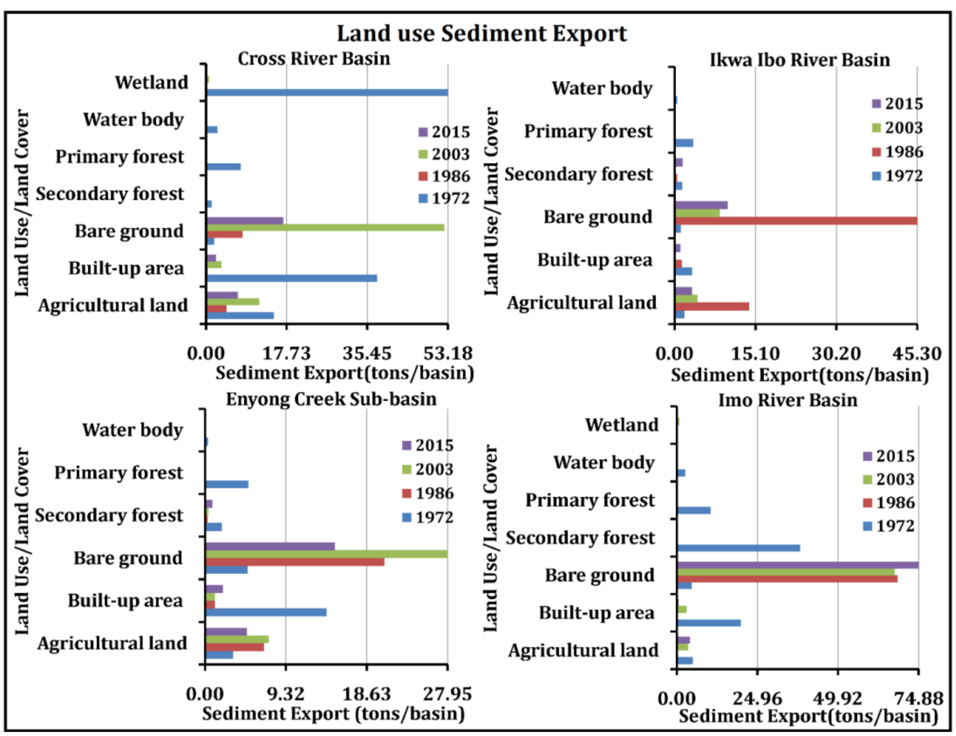

Figure 8. Land use sediment exported in Abia state hydrological basin for1972, 1986, 2003 and 2015.

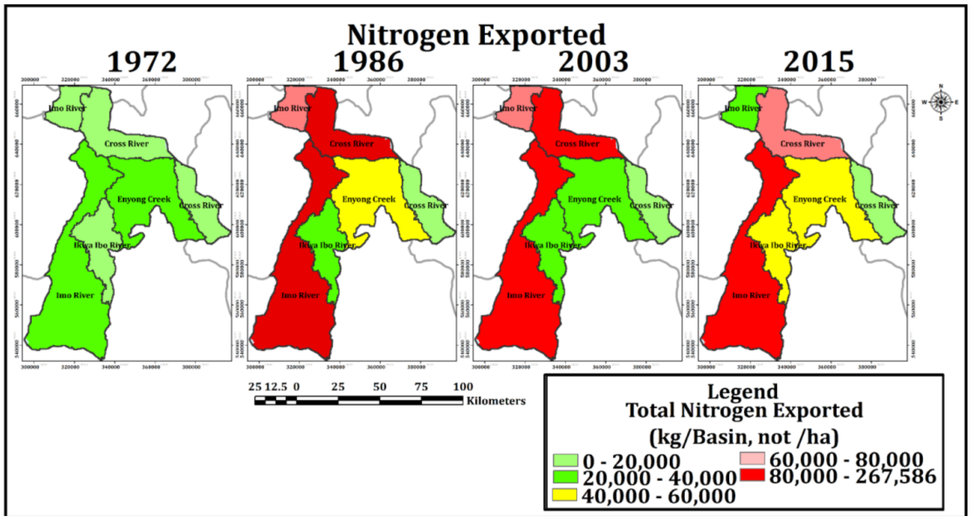

Figure 9. Nitrogen exported for Abia state in 1972, 1986, 2003 and 2015.

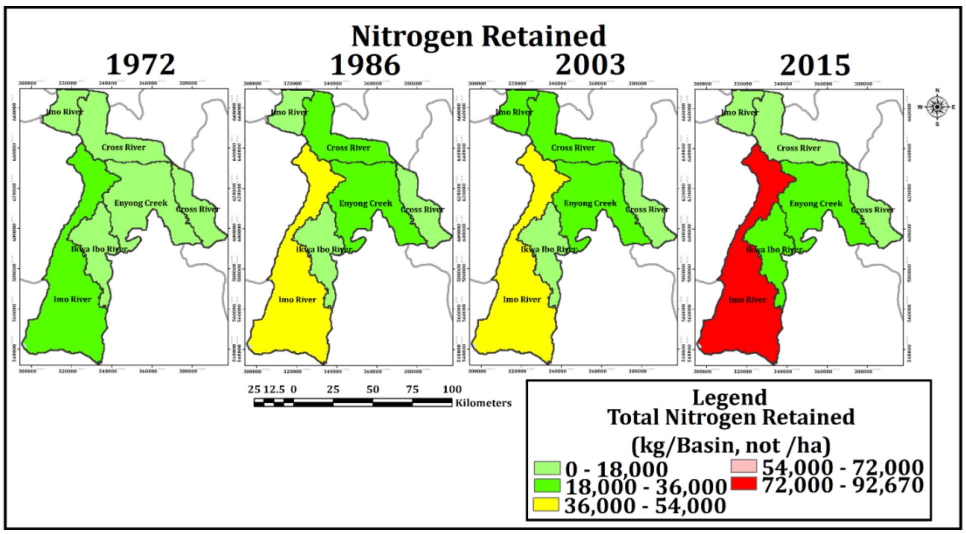

Figure 10. Nitrogen retained for Abia state in 1972, 1986, 2003 and 2015.

All LULC classes recorded a minimum of 0.00 kg/basin between 1972 and 2015, with a mean of 0.00 kg/basin for secondary forest and agricultural land in 1972 for nitrogen. In 1972 for agricultural land, nitrogen export was observed to be low with a maximum of 0.76 kg/basin. Built up areas was observed to export a maximum of 0.68 kg/basin and mean of 0.05 kg/basin of nitrogen in 1972. Bare ground was observed to export maximum of 0.77 kg/basin and mean of 0.14 kg/basin of nitrogen in 1972. Secondary forest was observed to export maximum of 0.53 kg/basin of nitrogen in 1972. Primary forest was observed to export maximum of 0.77 kg/basin of nitrogen in 1972. Water body was observed to export a maximum of 0.78 kg/basin and mean of 0.02 kg/basin of nitrogen in 1972. For 1986 and 2003, secondary and primary forest recorded a mean of 0.00 kg/basin of nitrogen. In 1986, for agricultural land nitrogen export was observed to be low with a maximum of 2.66 kg/basin and mean of0.01 kg/basin. Built up areas was observed to export a maximum of 3.01 kg/basin and mean of 0.71 kg/basin of nitrogen in 1986. Bare ground was observed to export maximum of 3.01 kg/basin and mean of 0.24 Kg/basin of nitrogen in 1986. Secondary forest was observed to export maximum of 2.44 kg/basin of nitrogen in 1986. Primary forest was observed to export maximum of 1.64 kg/basin and mean of 0.01 kg/basin of nitrogen in 1986. Wetland was observed to export maximum of 2.55 kg/basin of nitrogen in 1986. Water body was observed to export a maximum of 1.04 kg/basin and mean of 0.07 kg/basin of nitrogen in 1986. For 2003, for agricultural land a maximum of 2.77kg/basin and mean of 0.01kg/basin of nitrogen was exported.

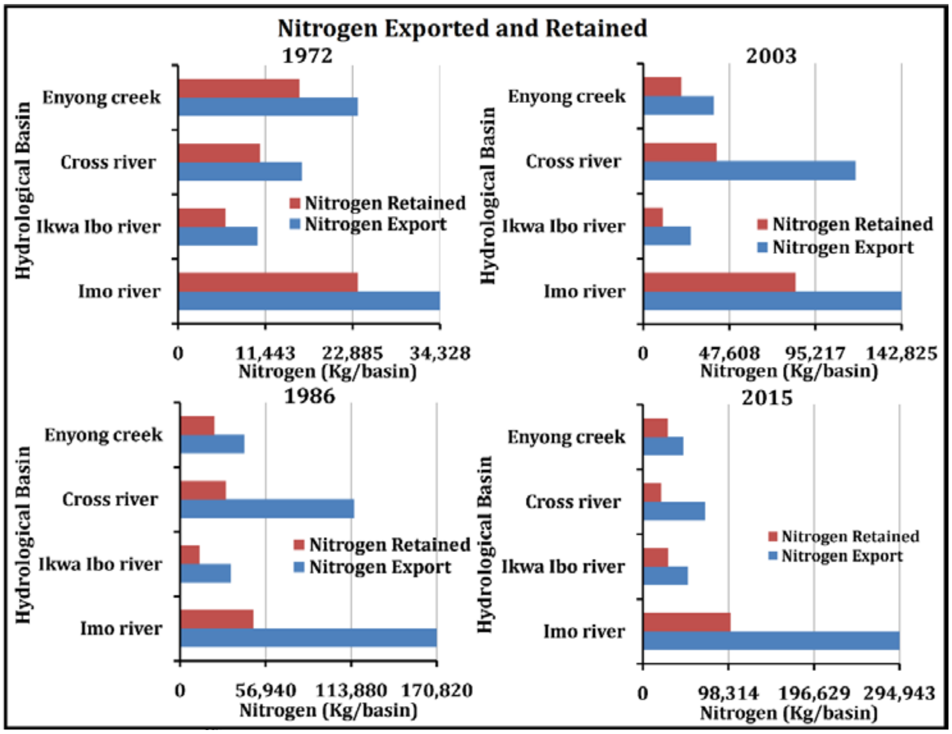

Figure 11. Nitrogen exported and retained for Abia state in 1972, 1986, 2003 and 2015.

Built up areas was observed to export maximum of 3.01 kg/basin and mean of 0.69 kg/basin of nitrogen in 2003. Bare ground was observed to export maximum nitrogen of 3.07 kg/basin and mean of 0.22kg/basin in 2003. Primary forest was observed to export maximum nitrogen of 0.97 kg/basin in 2003. Wetland was observed to export maximum nitrogen of 2.15 kg/basin and mean of 0.03kg/basin in 2003. Water body was observed to export a maximum of 3.16kg/basin of nitrogen in 2003. While in 2015, for agricultural land nitrogen export was observed to be low with a maximum of 3.13 kg/basin and mean of 0.06kg/basin. Built up areas was observed to export a maximum nitrogen of 3.03 kg/basin and mean of 0.60kg/basin in 2015. Bare ground was observed to export maximum nitrogen of 3.17 kg/basin and mean of 0.21 kg/basin in 2015. Secondary forest was observed to export maximum nitrogen of 3.13kg/basin and mean of 0.01 kg/basin in 2015. Primary forest was observed to export maximum nitrogen of 3.16kg/basin in 2015. Wetland was observed to export maximum nitrogen of 3.12 kg/basin and mean of 0.21kg/basin in 2015. Water body was observed to export a maximum of 3.03kg/basin and mean of 0.07kg/basin of nitrogen in 2015.

Figure 15 shows the graphical details of the distribution of phosphorous exported in Abia state hydrological basin for 1972, 1986, 2003 and 2015. All classes recorded minimum and mean phosphorus of 0.00 kg/basin for 1972, 1986, 2003 and 2015, with a mean of 0.00 kg/basin for 1972. For 1986 and 2015, agricultural land, wetland, secondary and primary forest recorded mean phosphorus of 0.00 kg/basin expect for wetland in 2015 with a mean of 0.01 kg/basin. In 1972, for agricultural land phosphorus export was observed to be low with a maximum of 0.57 kg/basin. Built up areas was observed to export maximum phosphorus of 0.59 kg/basin and mean of 0.05 kg/basin in 1972. Bare ground was observed to export maximum of 0.52kg/basin and mean of 0.01 kg/basin in 1972. Secondary forest was observed to export a maximum of 0.51 kg/basin of phosphorus in 1972. In primary forest, maximum of 0.58kg/basin was exported in 1972. Water body was observed to export a maximum of 0.57kg/basin of phosphorus in 1972. In 1986, for agricultural land phosphorus export was observed to be low with a maximum of 0.59 kg/basin. For built up areas, maximum of 0.66 kg/basin and mean of 0.16 kg/basin was exported in 1986. Bare ground, maximum of 0.66 kg/basin and mean of 0.07 kg/basin phosphorus was exported in

1986. Secondary forest, maximum of 0.54kg/basin phosphorus was exported in 1986. Primary forest, maximum of 0.36 kg/basin phosphorus was exported in 1986. Wetland, maximum of 0.56kg/basin phosphorus was exported in 1986. Water body was observed to export a maximum of 0.23kg/basin of phosphorus in 1986. In 2003, for agricultural land maximum of 0.61 kg/basin of phosphorus were exported.Built up areas, maximum of 0.68 kg/basin and a mean of 0.16kg/basin of phosphorus were exported in 2003. Bare ground, phosphorus maximum of 0.68kg/basin and mean of 0.06 kg/basin in 2003 was exported. Secondary forest, maximum of 0.26 kg/basin of phosphorus was exported in 2003. Primary forest exported maximum of 0.26kg/basin of phosphorus in 2003 was exported. Wetland exported maximum of 0.55kg/basin of phosphorus in 2003. Water body was observed to export a maximum of 0.48 kg/basin and mean of 0.01kg/basin of phosphorus in 2003. While in 2015, for agricultural land phosphorus export was observed to be low with a maximum of 0.51kg/basin and mean of 0.01kg/basin. Built up areas, maximum of 0.66 kg/basin of phosphorus were exported in 2015. Bare ground, maximum of 0.70kg/basin and mean of 0.19kg/basin of phosphorus were exported in 2015. Secondary forest, maximum of 0.67kg/basin and mean of 0.06kg/basin of phosphorus were exported in 2015.

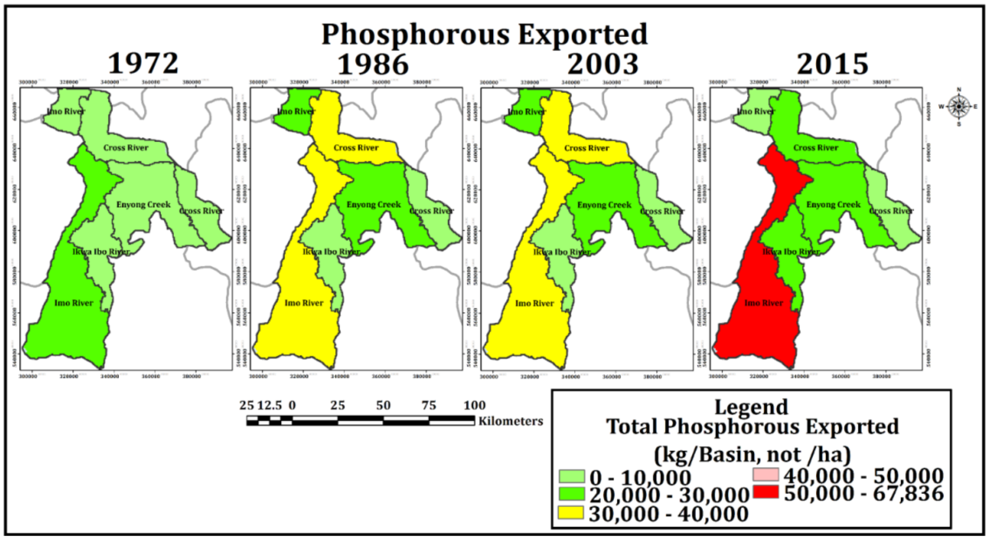

Figure 12. Phosphorous exported for Abia state in 1972, 1986, 2003 and 2015.

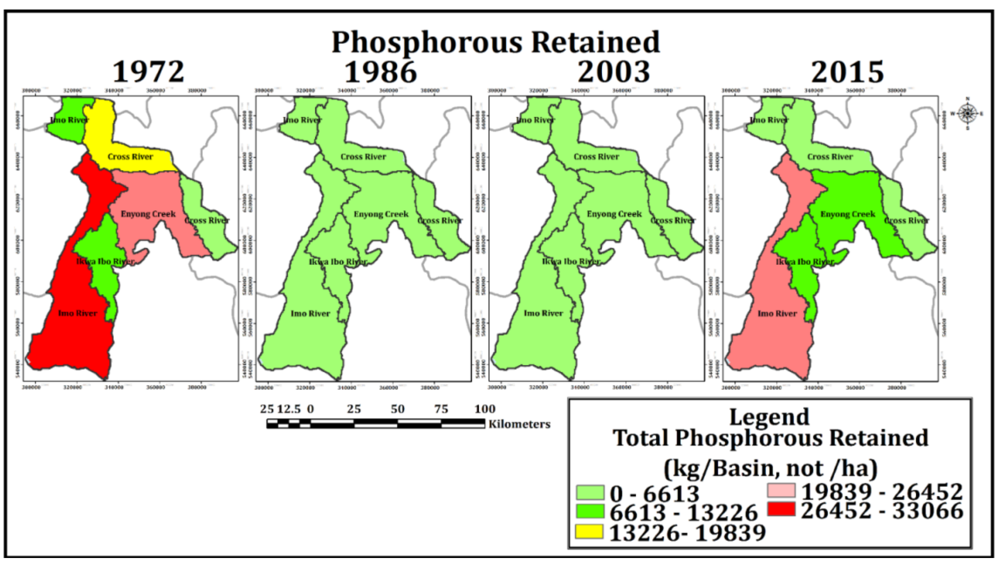

Figure 13. Phosphorous retained for Abia state in 1972, 1986, 2003 and 2015.

Primary forest a maximum of 0.62 kg/basin of phosphorus was exported in 2015. Wetland, maximum of 0.58kg/basin of phosphorus was exported in 2015. Water body was observed to export a maximum of 0.29kg/basin of phosphorus in 2015. The result reveals that LULC change in one area of basin can cause nutrient retention problems at other locations. Also, it was discovered that LULC with no filtering capacity have high export capacity, such as build-up areas, bare ground and water body. Thus, these are areas where investments in protecting this environmental service will provide the greatest returns and also where land use changes may have the greatest impacts on service provision.

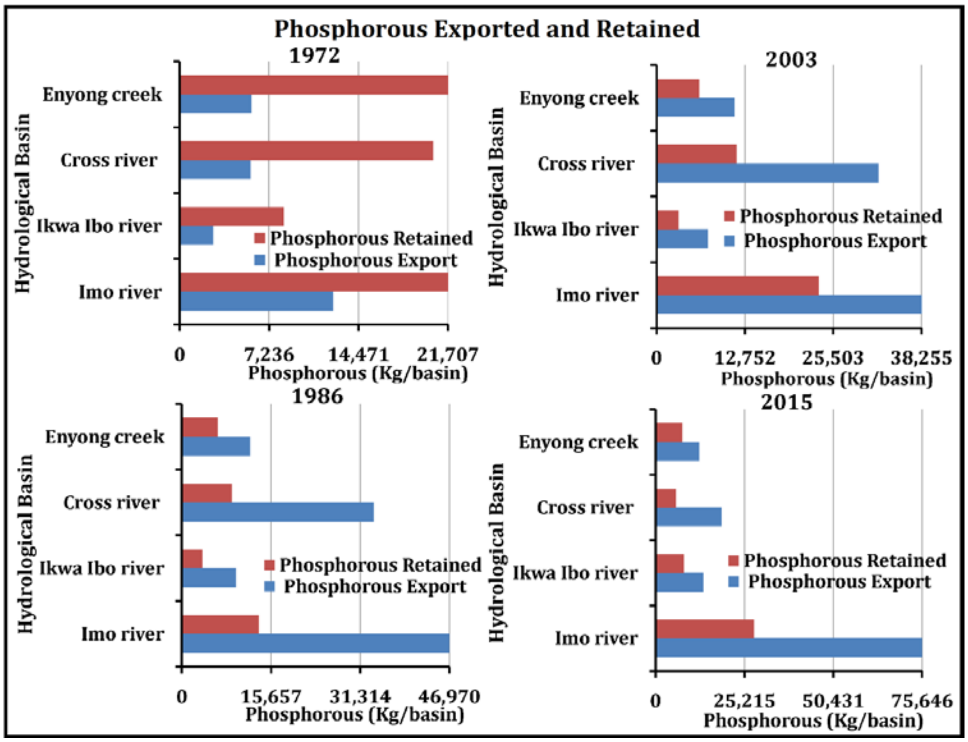

Figure 14. Phosphorous exported and retained for Abia state in 1972, 1986, 2003 and 2015.

Economic benefits and loss of Nutrient Retention on Abia state Hydrological Basin

Abia state hydrological basin is part of the Nigeria's hydrological basin, which supplies drinking water for Abia residents. Natural landscape characteristics, agronomic and economic conditions result in high nutrient (Phosphorus and Nitrogen) transport to the reservoir in amounts that affects current water quality standards. Environmental cost of water purification was computed and found to have a high economic value due to deforestation and high nutrient runoff in Abia state. Variation in the results has indicated that land use changes may have the greatest impacts on service provision and water purification. Figure 16 show the economic benefit of retaining nitrogen in 1972, 1986, 2003 and 2015 for Abia state hydrological basin. Figure 18 graphically shows the economic value of exporting and retaining nitrogen in 1972, 1986, 2003 and 2015 for Abia state hydrological basin. For Imo river basin in 1972, the economic value of nitrogen exported was found to be \$34328.00 and \$23551.20 for nitrogen retained with \$7667290.00 as the economic benefit (value) of the basin for retaining nitrogen over 14 years span. For Ikwa Ibo river basin in 1972, the economic value of nitrogen exported was found to be \$10378.50 and \$6172.31 for nitrogen retained with \$2318090.00 as the economic benefit of the basin for retaining nitrogen over 14 years span. For Enyong creek sub basin in 1972, the economic value of nitrogen exported was found to be \$16258.30 and \$10727.30 for nitrogen retained with \$3631355.06 as the economic benefit of the basin for retaining nitrogen over 14 years span.

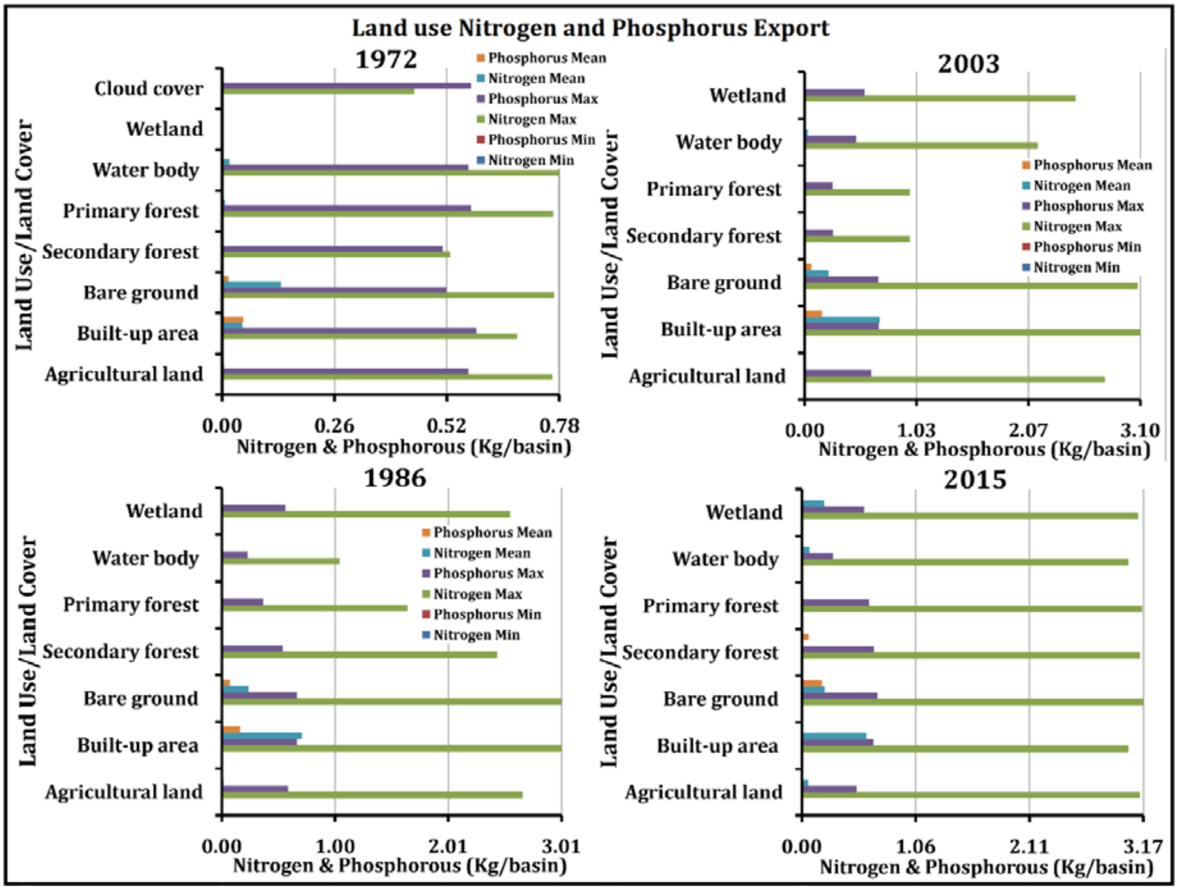

Figure 15. Land use Nitrogen and Phosphorus exported in Abia state hydrological basin for 1972, 1986, 2003 and 2015.

While in Cross river basin in 1972, the economic value of nitrogen exported was found to be $23552.30 and $15920.30 for nitrogen retained with $5260500.00 as the economic benefit of the basin for retaining Nitrogen over 14 years span. In 1986 for Imo river basin, the economic value of nitrogen exported was found to be $170820.00 and $48844.20 for nitrogen retained with $42610500.00 as the economic benefit of the basin for retaining nitrogen over 17 years span For Ikwa Ibo river basin in 1986, the economic value of nitrogen exported was found to be $33798.00 and $12923.00 for nitrogen retained with $8430760.00 as the economic benefit of the basin for retaining nitrogen over 17 years span. For Enyong creek sub basin in 1986, the economic value of nitrogen exported was found to be $115847.00 and $30363.80 for nitrogen retained with $28897620.00 as the economic benefit of the basin for retaining nitrogen over 17 years span. While in Cross river basin in 1986, the economic value of nitrogen exported was found to be $42767.20 and $22754.70 for nitrogen retained with $10668100.00 as the economic benefit of the basin for retaining nitrogen over 17 years span. In 2003 for Imo river basin, the economic value of nitrogen exported was found to be $142825.00 and $48844.20 for nitrogen retained with $42610500.00 as the value of the basin for retaining nitrogen over 12 years span. For Ikwa Ibo river basin in 2003, the economic value of nitrogen exported was found to be $26329.80 and $10633.50 for nitrogen retained with $7480480.00 as the value of the basin for retaining nitrogen over 12 years span. For Enyong creek sub basin in 2003, the economic value of nitrogen exported was found to be $117377.00 and $40502.80 for nitrogen retained with $33347390.00 as the value of the basin for retaining nitrogen over 12 years span. While in Cross river basin in 2003, the economic value of nitrogen exported was found to be $39041.90 and $21078.00 for nitrogen retained with $11092100.00 as the economic benefit of the basin for retaining Nitrogen over 12 years span. While in 2015 for Imo river basin, the economic value of nitrogen exported was found to be $294943.00 and $100540.00 for nitrogen retained with $65876660.00 as the economic benefit of the basin for retaining nitrogen over 12 years span. For Ikwa Ibo river basin in 2015, the economic value of nitrogen exported was found to be $51645.00 and $28945.40 for nitrogen retained with $11535100.00 as the economic benefit of the basin for retaining nitrogen over 12 years span. For Enyong creek sub basin in 2015, the economic benefit of nitrogen exported was found to be $71226.50 and $20896.20 for nitrogen retained with $15908700.00 as the economic benefit the basin for retaining nitrogen over 12 years span. While in Cross river basin in 2015, the economic value of nitrogen exported was found to be $46501.30 and $28405.50 for nitrogen retained with 10386200.00 as the economic benefit of the basin for retaining nitrogen over 12 years span.

Figure 17 shows the economic benefit of retaining phosphorus in 1972, 1986, 2003 and 2015 in Abia state hydrological basin. Figure 18 graphically shows the economic value of exporting and retaining phosphorus in 1972, 1986, 2003 and 2015 in Abia state hydrological basin. In 1972 for Imo river basin, the economic value of phosphorus exported was found to be $12398.30 and $23551.20 for phosphorus retained with $7667290.00 as the economic benefit of the basin for retaining phosphorus over 14 years span. For Ikwa Ibo river basin in 1972, the economic value of phosphorus exported was found to be $2711.83 and $8408.91 for phosphorus retained with $605699.00 as the economic benefit of the basin for retaining phosphorus over 14 years span.

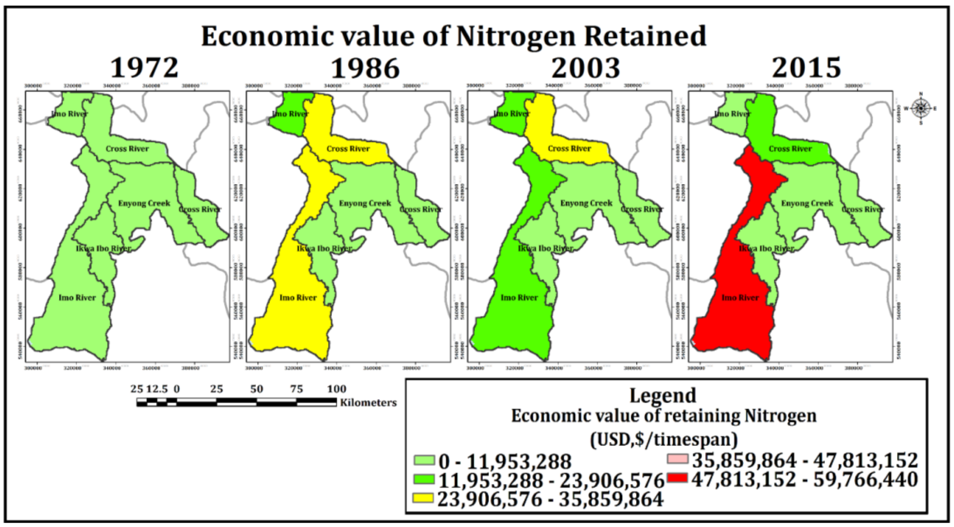

Figure 16. Economic benefit of retaining Nitrogen in 1972, 1986, 2003 and 2015 in Abia state hydrological basin.

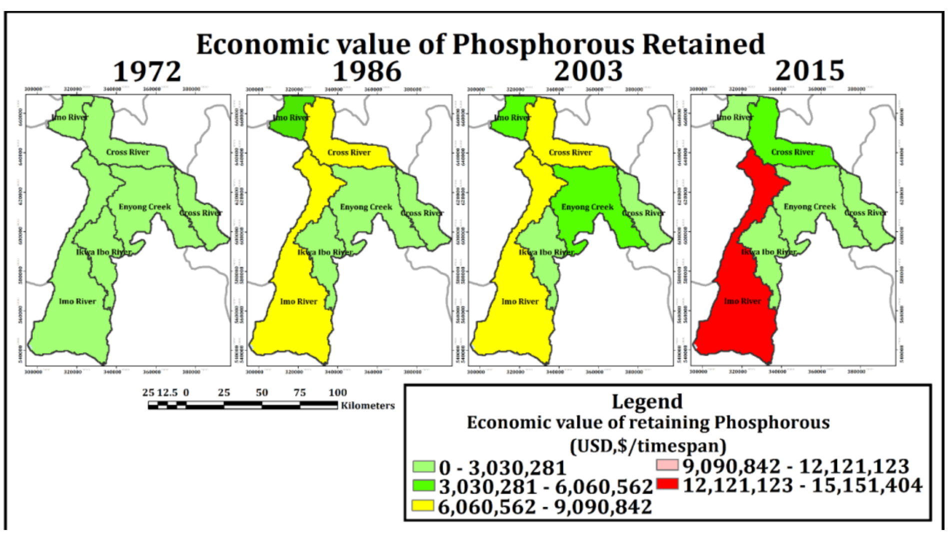

Figure 17. Economic benefit of retaining Phosphorus in 1972, 1986, 2003 and 2015 in Abia state hydrological basin.

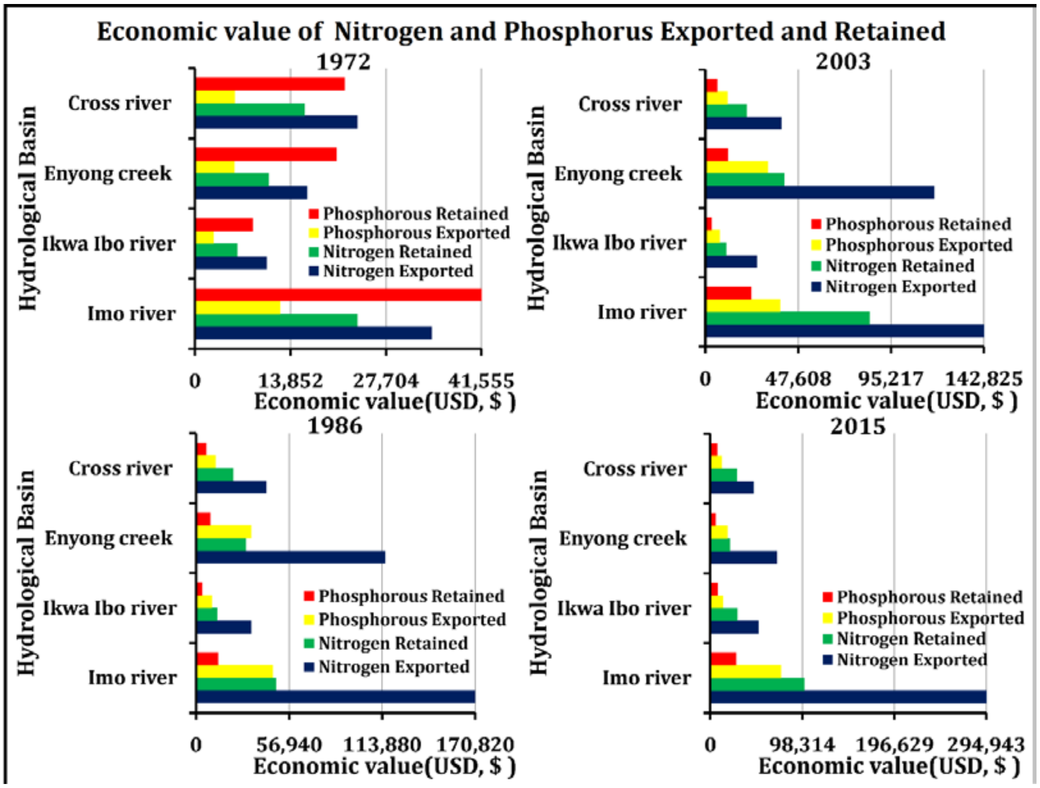

Figure 18. Economic value of Nitrogen and Phosphorous exported and retained in Abia state hydrological basin for 1972, 1986, 2003 and 2015.

For Enyong creek sub basin in 1972, the economic benefit of phosphorus exported was found to be $5747.68 and $21706.50 for phosphorus retained with $1290940.00 as the economic benefit of the basin for retaining phosphorus over 14 years span. While in Cross river basin in 1972, the economic value of phosphorus exported was found to be $5779.82 and $15920.30 for phosphorus retained with $5260500.00 as the economic benefit of the basin for retaining phosphorus over 14 years span. In 1986, for Imo river basin, the economic value of phosphorus exported was found to be $46970.30 and $13514.60 for phosphorus retained with $11716530.00 as the economic benefit of the basin for retaining phosphorus over 17 years span. For Ikwa Ibo river basin in 1986, the economic value of phosphorus exported was found to be $9476.83 and $3584.08 for phosphorus retained with $2363950.00 as the economic benefit of the basin for retaining phosphorus over 17 years span. For Enyong creek sub basin in 1986, the economic value of phosphorus exported was found to be $33661.60 and $8771.67 for phosphorus retained with $8396750.00 as the economic benefit of the basin for retaining phosphorus over 17 years span. While for Cross river basin in 1986, the economic value of phosphorus exported was found to be $11994.80 and $6311.25 for phosphorus retained with $2992050.00 as the economic benefit of the basin for retaining phosphorus over 17 years span. In 2003 for Imo river basin, the economic value of phosphorus exported was found to be $38255.20 and $23402.00 for phosphorus retained with $10868560.00 as the economic benefit of landscape for retaining phosphorus over 12 years span. For Ikwa Ibo river basin in 2003, the economic value of phosphorus exported was found to be $7378.98 and $3147.89 for phosphorus retained with $2096420.00 as the economic benefit of the basin for retaining phosphorus over 12 years span. For Enyong creek sub basin in 2003, the economic value of phosphorus exported was found to be $32031.50 and $11564.70 for phosphorus retained with $9100352.00 as the economic benefit of the basin for retaining phosphorus over 12 years span. In Cross river basin in 2003, the economic value of phosphorus exported was found to be $11214.90 and $6168.00 for phosphorus retained with $3186210.00 as the economic benefit of the basin for retaining phosphorus over 12 years span. While in 2015 for Imo river basin, the economic value of phosphorus exported was found to be $75646.40 and $27838.40 for phosphorus retained with $16895930.00 as the economic benefit of the basin for retaining phosphorus over 12 years span. For Ikwa Ibo river basin in 2015, the economic value of phosphorus exported was found to be $13469.80 and $7938.67 for phosphorus retained with $3008520.00 as the economic benefit of the basin for retaining phosphorus over 12 years span. For Enyong creek sub basin in 2015, the economic value of phosphorus exported was found to be $18709.70 and $5667.05 for phosphorus retained with $4178874.03 as the economic benefit of the basin for retaining phosphorus over 12 years span. While in Cross river basin in 2015, the economic value of phosphorus exported was found to be $12313.80 and $7521.79 for phosphorus retained with $2750330.00 as the economic benefit of the basin for retaining phosphorus over 12 years span. To offset the nutrient lost erosion inflicts on crop production; large quantities of fertilizers are often applied. The economic value of nutrients loss is higher than nutrients gained annually in Abia state between 37.29% to 40.69% in 1972, 20.00% to 37.73% in 1986, 25.65% to 37.11% in 2003 and 22.68% to 37.92% in 2015 for Nitrogen. While for phosphorous, between 75.61% to 78.97% in 1972, 20.67% to 34.48% in 1986, 26.53% to 37.96% in 2003 and 23.25% to 37.92% in 2015. While, it was discovered that replacement strategy is expensive for farmer and usually not affordable by poor farmers. Also, these fertilizers are inputs of fossil-energy; these chemicals can harm human health, affects current water quality standards and pollute the environment. However, the results reveals economic benefits of applying proper conservations through vegetation over the specified time span by identifying areas in the basin where investments in protecting this environmental service will provide the greatest returns.

Abia state Hydrological Basin Resilient Check

In Abia state, a resilient check was performed on the hydrological basin which is known as *Abia state basin* for 1972, 1986, 2003 and 2015. Figure 19 shows the Abia state hydrological basin resilient check map for 1972, 1986, 2003 and 2015. Figure 20 shows graphical details of the resilience of Abia state hydrological basin for 1972, 1986, 2003 and 2015. The resilient check explains the ability ofthe hydrological basin to response to change in land use in relation to soil loss, sediment export, nutrient export and economic value of nutrient loss. The hydrological basin resilient level has an impact on water quality, agricultural productivity and economy of Abia state.

Furthermore in Abia state, hydrological basin resilient check was performed for each basin as shown in Figure 21. In 1972, high resilient covers 18.66% of Imo river basin, 36.12% of Cross river basin, and 45.22% of Ikwa Ibo river basin while low resilient covers 54.31% of Imo river basin, 12.29% of Cross river basin, and 33.41% of Enyong creek sub basin. In 1986, very low resilient covers 44.33% of Cross river basin, and 56.67% of Ikwa Ibo river basin while low resilient covers 48.75% of Imo river basin, 25.24% of Cross river basin and 26.01% of Enyong creek sub basin.

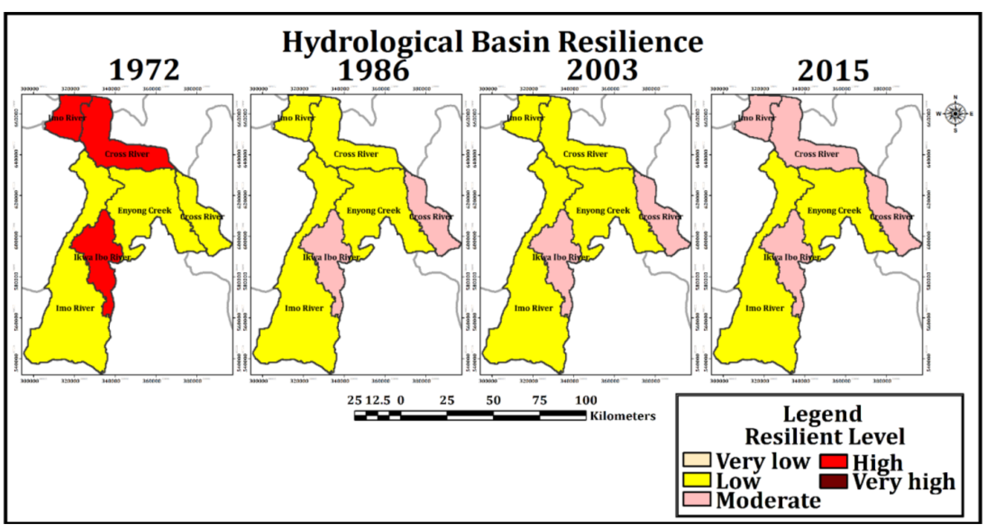

Figure 19. Resilience of Abia state hydrological basin for 1972, 1986, 2003 and 2015.

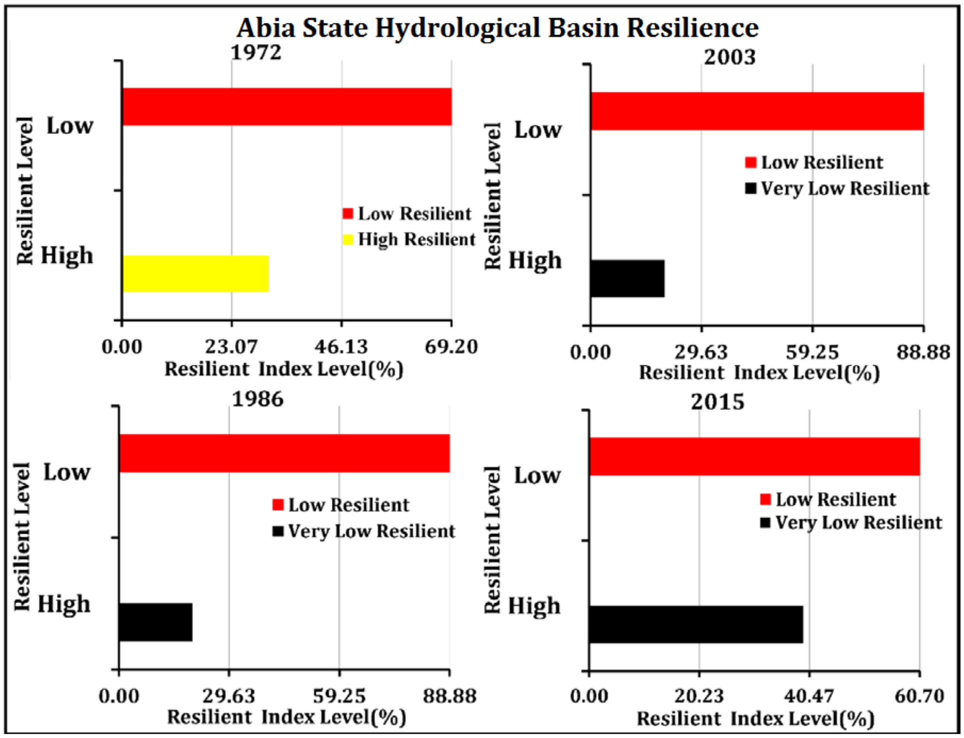

Figure 20. Resilience of Abia state hydrological basin for 1972, 1986, 2003 and 2015.

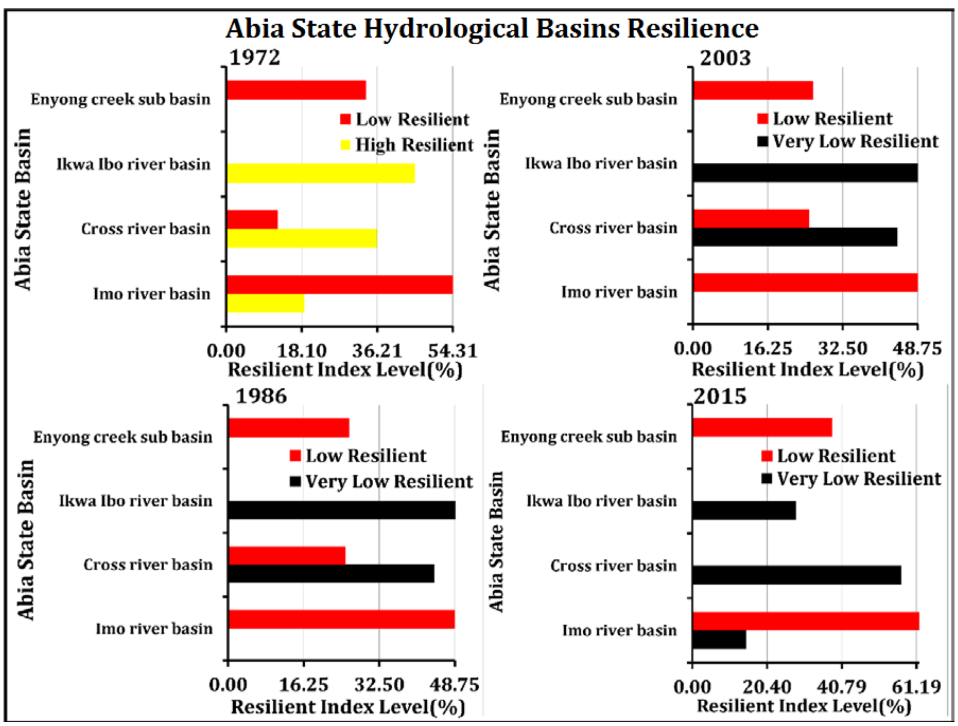

Figure 21. Resilience of the hydrological basins in Abia state for 1972, 1986, 2003 and 2013.

In 2003, very low resilient covers 44.33% of Cross river basin, and 56.67% of Ikwa Ibo river basin. low resilient covers 48.75% of Imo river basin, 25.24% of Cross river basin, and 26.01% of Enyong creek sub basin.For 2013, very low resilient covers 14.62% of Imo river basin 57.08% of Cross river basin, and 28.30% of Ikwa Ibo river basin. Low resilient covers 61.91% of Imo river basin and

38.09% of Enyong creek sub basin. The result implies a drastic reduction in the resilient level of the Abia state hydrological basin over time which is low between 1972 and 2015 as well as its agro-productivity, socio economic inequalities, human health and the overall well- being of Abia sate. This highlights the fact that proper conservation measures needs to be applied because this could serve as relief point to improve agro productivity, water quality standard and general well-being of Abia state.

CONCLUSION

The major findings of this study consist of quantifying and mapping the ecosystem service of sediment retention in Abia state basin. InVEST models was able to predict the spatial and temporal patterns of sediment and nutrient loading in Abia state (hydrological) basin. These calibrated models could then simplify future land use planning. Model allowed us to identify land uses, and areas, within the basin that have high potential for erosion, and to quantify the amount of sediment produced from sheet wash annually. This analysis was intuitively spot-checked with our analysis of physical erosion characteristics within the hydrological basin. The analysis made it abundantly clear that land use within the hydrological basin has the potential to significantly impact downstream sedimentation. Another major finding is that the models used from the InVEST software proved useful even for this small scale study, local study and returned relevant and credible results for both land cover modeling and ecosystem services modeling. The economic benefit per basin of filtration by vegetation delivered at the downstream point(s) of interest over the specified time span was analyzed and the economic values of the basin in- terms of gain or loss were properly evaluated in the light of environment sustainability. A resilient check was performed on the hydrological basin and result implies that a drastic reduction in the resilient level of the Abia state hydrological basin was observed over time between 1972 and 2015 which is low as well as its impact on agro-productivity, socio economic inequalities and the overall well-being of Abia sate. This highlights the fact that proper conservation measures needs to be applied because this could serve as relief point to improve agro productivity, water quality and socio-economic standard and the general well-being of Abia state.

Conflict of interest

The author declare that there was no conflict of interest.

Acknowledgment

I acknowledge later Mrs P.N. Ibeabuchi for her suggestions and guidance in the course of my academic endeavours and pursuit.

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