Land Governance in an Interconnected World
ANNUAL WORLD BANK CONFERENCE ON LAND AND POVERTY
WASHINGTON DC, MARCH 19-23, 2018

# SUSTAINABLE LAND MANAGEMENT: SHIELDING THE AGRICULTURE LAND WITH FLOOD MANAGEMENT AND WETLANDS

**SHAMSUDDIN AHMED**
York Centre for Public Policy and Law, York University
Shamsuddin.ahmed08@yahoo.ca

**Paper prepared for presentation at the**
**"2018 WORLD BANK CONFERENCE ON LAND AND POVERTY"**
**The World Bank - Washington DC, March 19-23, 2018**

## Abstract

This research explores the issues of shielding the agriculture lands that are affected by floods frequency while the wetlands habitats are dynamic for sustainable land management with infrastructure and environmental extenuation. Sustainable land management is ought to be concomitant with flood action strategy merging the erstwhile lenient of agro-ecological entities and local environmental profile. Problems of deforestation, soil degradation, wetlands and surface drainage, and decreasing biodiversity are widespread. Flood action strategy for a region is obviously pertinent to the analysis of inundation area compartmentalisation with flood forecasting, flood proofing and flood response scenarios for long-term solutions, including five obligatory options such as appraisal, priority, delineation, originalities, and model for sustainable agriculture land. The obligatory option is that sustainable land management shielding the agriculture land with the dispensation of flood management and wetlands habitats is inexorable to investment priorities in infrastructure planning to prevent the upset from hazard and vulnerability.


***Keywords*:** agriculture land, flood management, land use policy, sustainable land management, wetlands

# Sustainable Land Management: shielding the agriculture land with flood management and wetlands

## 1. INTRODUCTION

This paper explores to synthesise the issues of shielding the agriculture lands that are affected by floods frequency and wetlands habitat while needed for sustainable land management with infrastructure planning and environmental extenuation. In this case, optimality of sustainable land management is, therefore, ought to be concomitant with flood action strategy merging the erstwhile lenient of agro-ecological entities, social-ecological boundaries, and local environmental profile.

In the public policy agenda, land use-based zoning ought to be precise on agriculture land use concerning sustainable land management that signifies the abilities in local land resources for further use without any degradation and indeed in the attitude of Sustainable Development Goals (SDGs). Land use policy is an important indicator of land utilities by dominant-land-use by different sectors. Endeavors of Local Government Institutions (LGIs) are considered to be the persistent role in municipal affairs, especially in land use regulations patently by appraising the sectoral policy, regional treaties, and governments' statutes and public regulations associated with land use. For the land use policy model, appraisal of land resources, social and environmental impact indicators are thought to be imperative with local livelihood routine that is subject to the availability, suitability and sustainability of agriculture land.

There are analytics, critics and disputes on the efficient use of agriculture land in the most of the countries. We can differentiate the countries globally from the World Bank's classifications either by the income-group or to the regional context especially the low-income and middle-income group countries, where agriculture lands, including public assets and rural settlements, are often affected by the monsoon climate and seasonal inundation of land from floods, downpours or cyclones. High population pressure reinforces the geophysical and socioeconomic determinants that increasingly alters the natural environment without having substantive measures in wetlands and floods management with optimal drainage and resource interventions. A country's arable lands inhabit an increasing declined from Net Cropped Area (NCA) and food-crops production that consequently results in the lower food-crops index corresponding to a country's Gross Domestic Product (GDP).

Nonetheless, the common impediments in local land management appear many from the policy perspectives and the institutional settings. Some of the key constraints are: (a) disappointing performance of the public sector due to overly centralized and elite political structure; (b) sensitive implementation of physical planning against local needs a because of its placement at the municipal level only; (c) complication between informal land rights and mix of overlapping modern and traditional land laws; (d) higher population density with many pro-poor or displaced people; (e) lack of enforcement in land use control mechanism and investment priorities in infrastructure planning; (f) deficiency in monitoring the compliances of land use zoning regulations; (g) obstacle in land management system due to a significant level of unseen or improper transactions in land registration; (h) unsuccessful or inadequate housing opportunities to meet the rapidly increasing demand; and/or (i) under-utilized sources of revenue in property taxation.

Ostensibly, the most major causes of reduction in agriculture land ownership holdings are predominant with the social-ecological structure that indeed is reducing the rural livelihood dependency to the agriculture. Where a sustainable land management concern at least three phenomena such as (i) migration or transformation of agriculture land resources to the urban and commercial areas; (ii) expansion of rural settlements covering the arable lands; and (iii) conversion of agricultural land for commercial use or short-term economic benefit. Moreover, deforestation evils, soil degradations, wetlands reductions and drainage obstacles, and biodiversity disparity have already turned into serious environmental concerns.

The relevance of land management is essentially multiple benefits, such as agricultural production, biodiversity conservation, water quality, soil health and human life support. Flood action strategy for a region is obviously apt to the analysis of inundation area compartmentalisation with “flood forecasting”, “flood proofing” and “flood response” scenarios for long-term solutions. Wetlands are naturally the depressed land surface that presents the low lying area comprising of both the open water bodies and the adjoining upslope of the water bodies that brings primary ecological functions. To ensure long-term sustainability, the land administrators need to consider economic, social and environmental factors that may relate at least three major dimensions of the land resources management: (a) environment management and (b) water resources management; and (c) housing and settlement development. Thus this study is organised into five sections. The following section outlines the data and methodology. Section 3 describes the issues and options needed for protecting the agriculture land with flood management and wetlands while Section 4 concludes.

## 2. DATA AND METHODOLOGY

The sources of data were secondary data; the government published records and review of field observations and case studies of agricultural land dominant rural habitats. Appraisals of data are mainly threefold: geophysical aspects, socio-economic perspectives and institutional and policy context. Review of geophysical aspects accomplished by GIS database, satellite imageries and spatial analyses while the socioeconomic data includes analyses occupational households that are habitually dependent upon livelihood opportunity and income sources. Data were rigorously studied considering population distribution pattern, household occupational pattern, flood scenarios and the wetlands habitats in connection with the agriculture lands protection. In geophysical relations, location-specific correlation of occupational households with agriculture land holdings has been studied to characterising the needs of land use zoning at the local level.

The principal parameters for appraising land use zoning are agro-ecological zone, soils physiography, land topography, administrative jurisdictions, and revenue boundaries, physical infrastructure, and comprehensive land-use coverage such as settlements, agriculture, and water bodies. Technological interventions like geographic information system and remote sensing data are the most useful means to determine the cost-effective outputs of land use appraisal. Review of various data both at the national level and to land use observations were critical prior to analyses and interpretation. A country-level data review includes agro-ecological zone, acreage coverage, national policies, and identification of case study locations. Spatially visualisation of landscape with the defined physiographic units and simplification of Agro-Ecological Zone (AEZ) with pertinent soil textures associations considering plain lands, hills and terraces are crucial to understanding the geophysical characteristics of a land surface drainage system. Nonetheless, shielding the agriculture land with flood management wetlands habitats ought to be perused in the framework what we can term as APDOM that elucidates the key components to protect the agriculture lands with flood management and wetlands in the manner of sustainable land management that are stated in simplified network model **(Figure 1**).

- #1. Land Use **Appraisal** as a baseline assessment.
- #2. Land Use **Priority** for agricultural production
- #3. Land Use **Delineation** for management practice
- #4. Land Use **Originalities** with agriculture legacy
- #5 Land Use **Model** for sustainable agriculture

## 3. SHIELDING THE AGRICULTURE LAND WITH FLOOD MANAGEMENT AND WETLANDS

### 3.1 Convolution and Pragmatism in Water Resources Management

Hydrology of water resources estimation considers three physical states usually in the forms of liquid, solid, or gaseous. It dominates the critical environmental components (IEC) to verify the environmental impacts or development interventions that are predominant or occurred in an area over a particular timeframe. Such component can be an identification of change indicators, for instance, in flood depth-area-duration or flood extent-area from a time series or multi-temporal data using satellite imageries. Principal division of hydrology is two: groundwater hydrology and surface water hydrology. Characterization of hydrology especially in an arid environment relates a ‘vadose zone’ (Becker 2006: p311) that separates groundwater table from a surface water bowl.

The flow of groundwater randomly becomes visible at the surface and requires estimation of behaviour facts that often occurred from seasonal or storm influences. However, the variation and complexity of hydrological resource evolution are lessened by remote sensing technology and using satellite imageries to determine the effect of hydrological behaviour and their magnitude by components. In particular, monitoring and estimation of groundwater dynamics is relatively much complicated than that of surface water hydrology conversely by deploying Remote Sensing and Geographic Information System methods.

### *3.1.1 Surface water level monitoring and hydrological context*

In surface water hydrology, thematic issues in Canadian Remote Sensing are three components: water and soil moistures, snow and ice, and land surface (Pietroniro and Leconte 2003). Canadian Scientists predicted that the efficient use of GIS and Remote Sensing in Canada would require technological advances for future interference to meet the potential challenges in the use of geospatial information and management of water resources although there has been a real ability to measures spectral, spatial, and temporal information.

### *3.1.2 Groundwater flow and hydraulic driving force:*

Remote Sensing indicators or remotely sensed data for surface water hydrology components such as surface water (e.g., open water, snow, and terrestrial ice), soils moisture (a transitory state of land and waterfalls in wetlands), and land surface (land cover). In groundwater hydrology, the hydrological indicators or remotely sensed data are determined in association with a mathematical model considering groundwater flow or direction of the hydraulic driving force that relates flow functions (vector). Darcy’s Law that explains the relations the geological behaviours in groundwater perspectives what we can see as (Becker, 2006: p307):

$$q = K.\ I \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (i)$$

Where, $q$ = flow per unit area; $K$ = hydraulic conductivity sector; and $I$ = hydraulic gradient. Since there is no or less visibility of groundwater from a synoptic view, uses of remotely sensed data in groundwater estimation rather establish several factors resulting from the groundwater indicators in remote sensing of hydraulic potentials such as surface water depths, water column mass, heat capacity, land subsidence, and soil moisture. However, Becker agrees that classifications of groundwater recharge vs discharge areas using image-processing technique are instead a complicated practice. This complexity is predictable from the history of space through geographical evolution. 'Tessellati' (McNoleg 2003) had allied from the concept of spatial model and hydro-geological function with historical trends of an available geographic area and its emerging association.

For appraising a productive output using Remote Sensing and Geographic Information System (RS/GIS), in the ground of geodatabase derived from the hydrological scenario, an experimental methodology is necessary to establish a standard method. The examination in setting a methodology is subject to many reasons of which lack of adequate resources, topographical condition, and the operational timeframe in accomplishing the desired findings are significant.

### 3.2 Inundation Land Type and Flood Risk Dynamics: Tools and Procedures

The water sector has the significant consequence of land types while Area Elevation Curve and soils association data for the designated area of land use appraisal. Increasing development of infrastructure in transits, settlements and private houses affect the existing land types because of change in the regulated watercourses and the nominal flood water level. Consequently, topographical and hydrological changes upset the monotonous agricultural practices. For this reason, an apparent stipulation is to quantify the land types by extracting and evolution of mostly the digital spatial data and the plausible change dynamics in inundation land type types over the passage of time.

Digital data of land surface (land elevations) and flood surface (water depths) are inevitable to compute inundation land types, including temporal and spatial inundation. Development of applicable water surface models especially in a floodplain dominant land surface is a fundamental examination of flood scenarios especially on the eve of Bangladesh Flood Action Plan, 1991 ~ 1997. It commonly deliberated the model development and interpretations mostly in the 1990s especially in for local and regional hydrological project interventions assuming the flood occurrences. For instance, one in 2.3 years, one in five years, and one in 10 years predominantly in the floodplain lands with two options: (a) project condition with water-regulator (or embankment) and embedded or non-project condition without water-regulator (or without embankment).

In assessing the land type dynamics, the method of preparing surface area-elevation curve is to compute the area of ground lying within 100mm increments in elevation within each model segments where area consists of a group of distinct points in the surface and elevation means heights above the sea levels. Nonetheless, the accuracy of the area elevation curve (AEC) that remain a multifaceted process directly affect the confidence placed in the result of any analysis using geographic information system (GIS) and through digital elevation models (DEMs). DEMs can be compared further to the national topographic maps to predict a root mean square error while the accuracy of topographic maps allows the standard of absolute inaccuracies. To predict flood levels under different scenarios through mathematical models, significant data input to the models is a curve showing the relationship between the land surface and elevation for each segment of the model. In particular for the economic assessment of the flood interventions which is the estimate of the area of land to be protected from different levels of flooding while the area elevation curve is the key to such economic appraisal of lands.

### 3.3 Relative factors in agriculture, floods and wetlands occupancy

#### *3.3.1 Agriculture households' occupational pattern: Local Case:*

The occupational pattern of rural households is associated mainly with agriculture, agriculture labour and remittance while the sources of households' income are subject to the employment relation or livelihood opportunity. Purposively, occupational household analyses determine the rural employment opportunity with agriculture land or farm holdings and other sources of income about significant land use and relative impact and sustainability, particularly at the local level. Reviews of recent studies relating the "agriculture policy development paradigms" (Ahmed, 2016) reveal the converse correlations or undulating effects of the Overseas Development Assistance (ODA) with the three relevant entities such as agriculture lands, rural population, and the GDP share from agriculture production.

A declining trend in food crops index also appears while public investments mounted the abilities in rural infrastructures such as road network, rural electrification, and safe water and sanitation. The newly developed urban areas transformed from rural habitats that have higher growth of settlements and population coverage in a decade. Land zoning and management controls are necessary for the optimum use of land resources where agriculture lands and the sector associated contribute substantially to the domestic product of a country.

#### *3.3.2 Watercourses and surface drainage system- country case:*

Natural watercourses and surface drainage of the country is subject to the development obstacles nested because of increasing infrastructure, housing and settlements, where the land tenure system is obligated by the unplanned development of local municipalities and rural growth centres. Wetlands and floodplain lands are subject to the seasonal and temporal variation of water extent and flood frequency that affects agriculture, for example, what can be imaginable at the national level (**Figure 4**). In this situation the following are predictable determine the best use of agriculture lands as:

- Challenges in agriculture use of wetlands
- Aerial extent of soils saturation and temporal inundation
- Computing technology for the reclamation of wetlands and traditional agriculture practices -
- Growth pattern in wetlands and agriculture
- Flood frequency and conservation losses in wetlands
- Flood storage and hydrologic flux in the Environment and Ecosystem,
- Floodplain Wetlands Inundation – impact of dam in seasonal agriculture reclamation
- Flood, Wetlands and Agriculture- Information Technology and Data Management
- Flood monitoring**-** land and water classifications

*3.3.3 Wetlands habitats and water-agriculture pattern: Ramsar Case:*

Wetlands habitat monitoring review based on a field study (Ahmed, 2006) described GPS (global positioning system) data that were identified with some key attributes for a total of 174 spots covering approximately 250m radius area. Of which, 74 spots (57.8 ha) at ECA boundary and 94 spots (62.7 ha) in ECA interior area **(Figure 2**). These spots are two separate characteristics- (a) ECA boundary definition data, and (b) ECA habitat in a central location. Categorically, habitat pattern is heterogeneous because of the existence of agriculture occupancy in wetlands habitats. At ECA boundary, the community has a high resource intervention by increasing encroachment or agricultural land towards ECA interior locations of “Hakaluki Haor” as one of the designated Ramsar Site located in Northeast Bangladesh.

Environmentally, Hakaluki Haor wetlands are a globally important home for a wide variety of migratory and local birds and a Centre for natural swamp forests generation or regeneration. It had abundant aquatic vegetation that provided rich grazing for domestic livestock and alternative fuel woods for the local community. Predominantly, the area demonstrated a freshwater wetlands ecosystem that covered nearly about 40,000 ha of an area including 12,000 ha ~ 18,000 ha of seasonal water coverage depending on magnitudes surface runoff, flash floods or torrential rains. Historical data showed that average maximum level water at Kuntinala-Juri station (135A) reached to 13.60 meters in 1985 and 13.16

meter in 1988, wherein 1967 it was 10.53 meter. The average annual rainfall emerged ranging from 4,320 mm to 5,840 mm. There was also a significant level of flood duration that affects agriculture crops while high water-level and incidences of flooding pose an excellent regeneration of wetlands resources. The exact area, in the dry season, was unmeasurable because of the sizes or extent of water bowls that are abridged by imbalanced sediment loads. It apparently caused by flash floods during torrential water period (May – September) and impediments of cross dams by the local people during the dry season (January – April). Agro-ecologically, the physiography is middle floodplain (Surma-Kushiyara) with a non-calcareous gray soils texture that has merely one seasonal crop (Boro) cultivated around the year (Brammer 2002; IUCN Bangladesh 2002; Field Observation 2005).

In assessing wetlands-dominants biodiversity hotspots at Hakaluki Haor, GPS spots, and associated data were integrated to estimate location-specific biodiversity existence. An area of 250m radius observations, as pre-defined, has been measured for habitat area inference in the percentage of total spot coverage. The 250m radius further locates a subset comprising a 20mx20m area to ensure magnitude of species diversity at the micro level. Even so, the huge observation spots may result in the main classifications with at least four significant coverages. The classifications of such spatial data demonstrate the existence of four land coverage prominent with the following characteristics:

- Forests mainly the swamps or seasonally degraded forests while periodical ecological succession appears during monsoon;
- Waterbodies including capture fisheries while agriculture and seasonal fallow or single cropland along the "ecotone";
- Settlements including homestead area without integrating some small land use coverages such as vegetables, plants or monoculture area; and
- Sizes of water bowls are abridged by imbalanced sediment loads apparently caused by flash floods during torrential water period as well human intervention during the dry season

Therefore, in a dominant wetland habitat, agriculture pattern is interfered by community pressure or human interventions that indicate three major habitat areas such as settlement, homestead and agricultural land where water coverage retains at least 20 percent can be treated as potential biological diversity with crops cultivation. The wetlands designated area considering the large reveals that cumulatively agriculture, settlement, and homestead area have some significant coverage where fallow lands, above 90 percent, are also declined from the suitability of agricultural and other biological diversity. Degraded swamp forests, a good number, indicate the land coverage where water body existence is accessible to at least 20 percent of the coverage area.

In comparison, water bodies indicate a relative representation of common area at the inside and outside of the core wetlands. Boundary data usually give the impression of the somewhat non-existence of swamp or degraded swamp. It is apparently as a result of community interventions along the ecotone. What we can illuminate as (Davie, 1997; Kark, 2013: p147), “the zones of transition between adjacent ecological systems" and “having a set of characteristics uniquely defined by space and time scales and by the strength of the interactions between them.” In other words, Ecotone changes the shape of ECA boundary based on the distribution of biodiversity. Boundary and interior data collated have a significant agreement among the habitats such as field vegetable, aquaculture or capture fisheries that also demonstrate a non-linear relationship between the two distinct locations.

### *3.3.4 Wetlands and Flood frequency in Prairie Province: Canada Case*

In Canadian Prairies, wetlands and flood scenario perhaps undoubtedly necessitates the bid for sustainable agricultural land management practices around a vast majority of the wetlands (Agriculture and Agri-Food Canada, 2015). It somewhat appears with ill-assorted ecology in agriculture perspective that endures the challenges with the ecologically sustainable approach, contemporary industrial agriculture and environmentally economic development. On the other hand, uncertain wetlands loss versus flood frequency appears to be paradoxical situation agriculture development and wetlands conservations. It indeed necessitates a long-term peruse of wetlands ecosystem and flood frequencies for sustainable agriculture management practice—where flood management and wetlands need the development cycle to understand flood forecasting, flood proofing and flood response models to widely determine the following aspects:

- natural wetlands and drainage pattern in an agriculture landscape
- soils, landscape and water quality impacts on wetlands
- Upland management impacts on wetlands
- Specific land management practices near the natural wetlands
- Sustainable land management in the midst of changing climate.

## 3.4 Sustainable Land Management Practice and Model: APDOM

While rapid expansion of infrastructure and settlements create impediments on watercourses and surface drainages of a particular area such as hydrological zone, catchment basin or local floodplain land. Problems of deforestation, soil degradation, wetlands and surface drainage, and decreasing biodiversity have already turned into serious environmental concerns not merely the country-level but regionally and across the sphere. Increasingly, flood scenarios in some of the OECD countries instead draw the attention of the respective individual country, the global community and the International Development Agencies (IDAs) to protect the ideology of Sustainable Land Management in an absolute form.

Unavoidably, land use and its precise delineation to shielding the agriculture lands with flood management and wetlands habitats need an Integrated Land Zoning Information System (ILZIS) (Ahmed, 2007). We can comprise the lessons learned at least with the following major aspects what can be abbreviated as APDOM model for the sustainable land management practices. It explicitly renders five major components mentioned in the data and methodology section. Specifically, #1 land use appraisal as baseline assessment (section 4.1.1); #2 land use priority for agriculture protection (4.1.2); #3 land use delineation for management practice (4.1.3); #4 land use originalities with agriculture legacy (4.1.4); and #5 land use model for sustainable agriculture (4.1.5).

### *3.4.1 #1. Land Use* ***Appraisal*** *as baseline assessment*

Analysis of land use and development intensity considering land management practice, population and dwelling density, countryside land use, wetlands habitats, and the predetermined public area about Agro-Ecological Zone (AEZ). Typically the physiographic unit simplifying the Agro-Ecological Zone **(Figure 4)**; Agro-Ecological zones (AEZs) are the geographical areas that exhibit analogous climatic environments in determining the ability to support agriculture under rain-fed condition. Factors such as latitude, elevation, temperature, seasonality and rainfall amounts and distribution during the growing season influence the AEZs especially at a regional scale.

Nonetheless, AEZs represents the physiographic unit of a country or a region that has to be in line with the environmental profile examining three major states of flooding such as flood forecasting (pre-flood stage), flood proofing (flooding stage) and flood response (post-flood stage). All of these entity-sets and attributes are to be considered for land use appraisal as the baseline information is prior or simultaneously to the significant investment in agricultural food-crops production. Factually, an optimal assessment of baseline information needs wide ranges of resources in an integrated planning and management option, however, not excluding the following:

- Technological resources, expert knowledge and innovative measures for ground information processing;
- Participatory action plan development by incorporating all designated stakeholders and the development partners; and
- Setting up institutional goals with exit strategies for the new initiatives and ensuring the top management commitment.

### *3.4.2 #2. Land Use **Priority** for agricultural production.*

Understanding the land use issues and potentials by reviewing the designated conservation sites, existing drainage system, topography and slope, and transit systems connecting the rural roads and growth centres. Projection of flooded inundation depth-area-extent analyses are thought to be substantial inputs especially with Exclusive Economic Zone (EEZ, see: United Nations Convention on the Law of the Sea (UNCLOS), 1982. Part V, Article 55). EEZ is the adjoining area connecting the land acreage coverage, including delineating the oil and gas blocks of a country demonstrating a typical Land Acreage and Gas and Oil Blocks overlapping the Exclusive Economic Zone **(Figure 5)**. Each country, in their own agenda, should have ensured optimal infrastructure and settlements conditions complying adequate surface drainage system and river water navigation route in all seasons showing of the major surface drainage and navigation route (**Figure 6**).

### *3.4.3 #3. Land Use **Delineation** for management practice.*

The eminence of impervious land and use restrictions firmly by developed, developing and underdeveloped or problem areas where the development of a country's local Digital Elevation/Terrain Modelling (DEM/DTM) is crucial to:

- Reclassification of inundation land types based on the symmetric differences and categorical coding based updating or new creation of digital <u>land elevation</u> surface elevation and digital <u>water level</u> surface; and
- Consequently, assessment of inundation risk of land with depth-area-duration by generating <u>land area elevation</u> curve and <u>water volume depth</u> curve in the context of surface water hydrology.

### *3.4.4 #4. Land Use **Originalities** with agriculture legacy.*

Examination of neighbourhood development plans including, population and business patterns, heritage and environmental conservations, and infrastructure type, intensity and facilities that are available to the adjoining area and subject to the soils texture, water availability, and land suitability plausibly with "reconnaissance" soils associations. This issue can be linked to the disaster management associated to the preventive measures of flooding and other disasters such as cyclone, tsunami and earthquakes.

### *3.4.5 #5 Land Use **Model** for sustainable agriculture.*

Ideal use of land with a long-term policy model especially by conserving agriculture lands that should include the wetlands habitats and rural settlements where sustainable land management would bid to delimit a land use policy model. It will also consider the principal entities and attributes as applicable with matrix and model implication what can typically be transformed form the "key aspects of land governance" to a policy framework (Ahmed, 2014).

## 4. CONCLUSIONS

This research concludes that apart from problems and challenges, there are possible considerations to apprehend the sustainable development of land management to meet the challenges to the sustainable agriculture lands and management practices. Factors such as severity of floods frequency, vulnerability of local food-crops, ecologically critical areas, public health and environmental issues, trans-boundaries & environmental externalities, and the institutional settings on the environment and climate change adaptation issues are predominant. On the contrary, this paper outlines to offer a synthesis of reviewing the physical environment such as land topography, physiography and inundation features of the designated areas signifying the permissible agriculture lands, rural settlements and wetland habitats—where five components (Figure 1) to accelerate the sustainable agriculture lands protection would be applicable. In conclusion, the obligatory option is a "land use policy model" for "sustainable land management" shielding the agriculture land with the optimal processing of flood management, and wetlands habitats are inexorable to the investment-priorities in infrastructure planning to prevent the upset from the local disaster, hazard and vulnerability.

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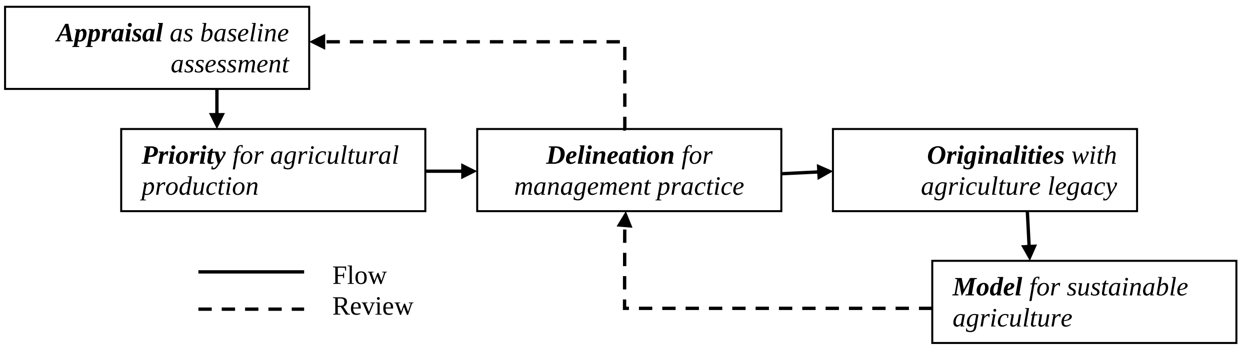


*Figure 1*: Simplified network model of shielding the agriculture land with flood management and wetlands in the sustainable land management practice

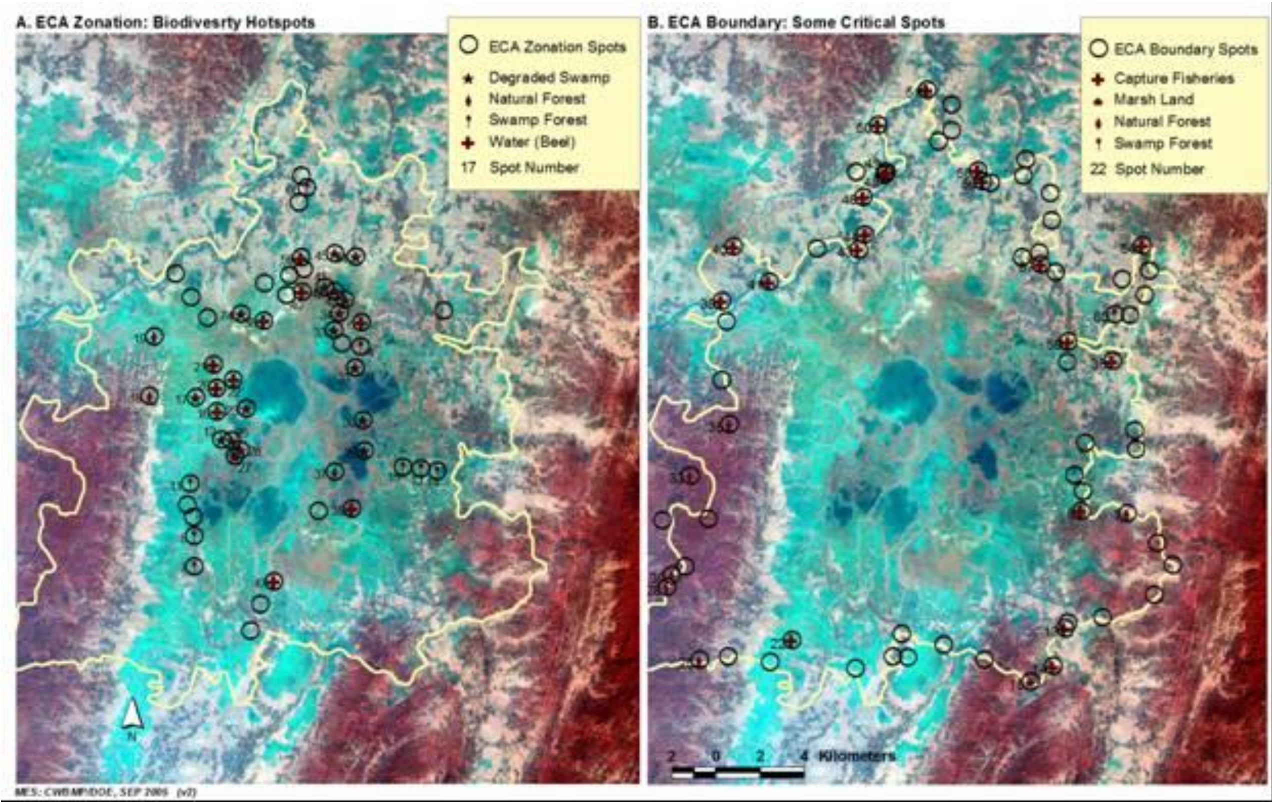


*Figure 2*: Ground observation spots with GPS readings in (February – April 2005), A. Within the Study Area, and B. at Boundary Locations; the background is Landsat ETM+ image (January 2003); Source: Ahmed, 2006

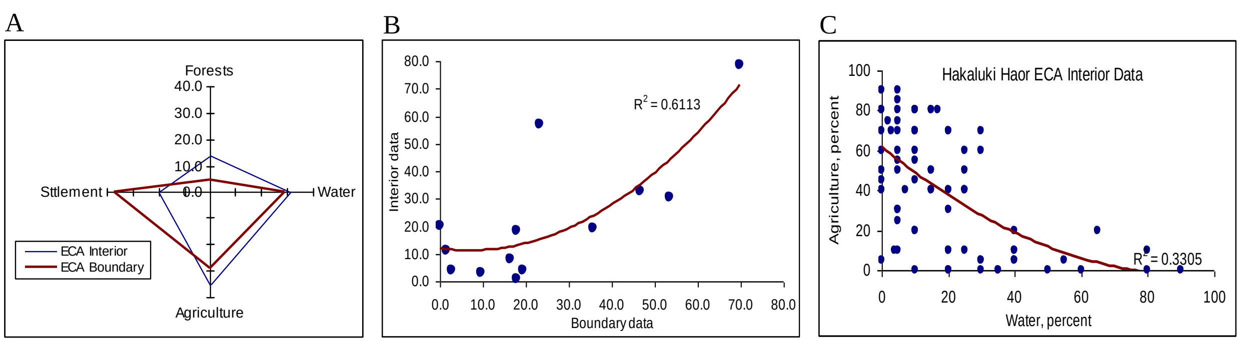


*Figure 3*: An Ecologically Critical Area is showing the distribution of typical wetlands habitats: A. Distribution ratio (in percent) of major land coverage; B. Relationship between boundary data and interior data in percent, and C. Agricultural land versus water coverage distribution in the designated area (Source: Ahmed, 2006).

Figure 4:

Figure 5:

Figure 6:

Figure 7: