ORIGINAL RESEARCH PAPER

Environmental Science

WETLAND INVENTORY, ASSESSMENT AND MONITORING

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ABSTRACT

The destruction caused to natural resources by human activity to a certain extent is rectified by the wetland, but the pace of disappearing wetland created a situation to find requisite program and tool for Wetland Inventory, Assessment and Monitoring. Several organizations are working cumulatively designing methodologies and policies to restore and improve the biotic characteristic. Wetland inventory provide guidance for the systematic collection of resource data using both tradition manual and advanced remote sensing tools. Whereas Wetland assessment includes identification of ecological stature and extent threat caused. Wetland monitoring is collection of information of the assessment activities as a result of the management and conducting surveillance in the existing and reduced threat. This review discusses the various methodologies followed by different situations around the globe.

INTRODUCTION

Water is the immense necessary resource of all living forms on the earth. The land area which is surrounded by water will have a distinct ecosystem and characteristic vegetation. Such lands are called Wetland (Ramsar Convention). These wetlands are transitional areas uniting terrestrial and aquatic ecosystems having rich vegetation that give rise to several human civilizations proving the importance of the water and wetlands.

Not only in days of yore, even today the impairment being caused to nature owing to urbanization, increasing population, and industrialization has been rectified by the sustainable indigenous biota of the wetland. Forests serve as 'lungs of the earth' whereas wetlands function as 'Kidneys of the earth' (Junhong Bai, 2013). Wetlands provide several remarkable services to the nature and human population by its ecologically sensitive functioning system.

Some of the many benefits we derive from wetland includes:

a) Providing habitat for many different species of wild life including fish, insects, amphibians, reptiles, birds and mammals.
b) Flood control and streamflow maintenance by absorbing and storing of water during heavy rain or from streams, then releasing them slowly over time during periods of drought.
c) Controls erosion facilitating a basin for retaining organic matter and silt of the soil, serving as sedimentation area and stabilization of stream bank.
d) Enhances quality of the water by filtering pollutants, removing the toxins and absorbs silts as a natural water purifier for both surface and groundwater.
e) Serves as a productive ecosystem, a specialized plant habitat.
f) Educational and recreational activities like fishing, canoeing, animal and bird watching, sightseeing, photography, hiking are organized.

So likewise provisioning services, regulating services, habitat or supporting services and cultural services (wetland ecosystem services Beverley R Clarkson chapter 2014) is provided by the wetland areas.

However today wetlands are under threat and disappearing three times faster than the forest. The reason behind this is due to increased human population and his greed to exploit and excessive use for its ecosystem. Factors responsible for the wetland ecosystem destruction can be distinguished as Wetland loss and Wetland degradation. Wetland loss involves the reduction in the wetland area, it is due to human activity like Agricultural conversion, Housing, roads construction and urbanisation. Whereas wetland degradation involve the reduction in the wetland function like reduced water quality, loss of biodiversity (MOSER et al. 1996), hydrologic activities for construction of canals and dams, release of chemicals from industries, agricultural pesticides, climate change and other anthropological activity (Gell et al., 2013). Inadequate knowledge and awareness of the ecosystem, economic and social advantages of the wetland led to the increased transforming of wetland to Agricultural lands (Afework et al., 2015). Lack of precise policies is the establishment of industries, construction of dams and unregulated management of urbanization leads to intervention in the balanced wetland ecosystem (Birhan et al., 2015). Draining of wetland has been known since Roman times in Europe (Davidson et al. 1991) and at least during the 17th century in North America (Dahl 1990). but widespread and raised as concern reported in the later 1920 in North America (Schmidt 2006). Several assessments conducted in the last 50-60 years have stated that there is decrease in the 50% of the wetland globally (Dugan, 2005), (OECD 1996), (Finlayson et al., 2005) reduction in the mangroves which belong to inland wetlands (Perennou et al. 2012), degradation of wetland by peat mining

(Harmon 1981), are few cases as examples.

Degradation of wetland has potential impact on Regional ecological security, health of humans, regional climate and biodiversity. Hence it has become a critical task to restore and protect (Junhong Bai, 2013). Many ecological conferences related to international wetlands are put together to form wetland restoration as a theme with the objective emphasizing the effect of human activities on wetland ecosystem and restoration plans and its application. Conservation and improving of the wetland is relatively priority function in the present days, in collaboration with the local communities, many government and non-government organization has implemented restoration strategies and plans in the form of programmes, such programs have put hands together by international organisations like UNESCO The United Nations Educational, Scientific and Cultural Organization, NRCS Natural Resources Conservation Service, IUCN International Union for Conservation of Nature, Wildfowl & Wetlands Trust WWT supporting the cause. Ramsar convention is one such international treaty which was signed in 1971 in Iran for the conservation and sustainable use of wetlands, it includes 171 countries as contracting parties with over 2,000 designated sites of wetlands which cover the 200,000,000 hectares of land. International organizations like IUCN, UNESCO, WWT, IWM and many more are the IOPs – International organization partners, they provide technical advice, financial support and help to implement field studies in different sites(countries). Every three years the representatives of the contracting parties have a meeting at the Conference of the Contracting parties COP to make new policy and make decisions in the present resolutions and new recommendations. Several such organisations have been established and working cumulatively on different methodologies in monitoring and Assessment of these wetlands. Their programme includes planning suitable approaches, designing protocols, implementing, monitoring and evaluating their effect.

Definition and correlation between Wetland Inventory, Assessment and Monitoring terminologies.

According to the Ramsar definition for the wetland is "Wetland includes areas like marsh, fen, peatland, swamps, bogs, lakes which may be seasonal or permanent and also man made or Natural". The wetland inventory, assessment and monitoring are the major steps in the wetland management. The critical information of the location, characters and distribution of wetland is the initial step for planning and decision-making of wetland management, protection and restoration is called Wetland inventory, and the data obtained during the inventory provide provision for the specific assessment based on the information and monitoring of the activities. Wetland Assessment is the process of identification of the ecological status and extent and the reasons for the threat caused by monitoring. And the Wetland monitoring is collection of information of the assessment activities as a result of the management and conducting surveillance in the existing and reduced threat. Management action taken to redress the changes in threat. Hence wetland inventory, assessment and monitoring are recognized as ideal essential tools for management action.

INVENTORY

As Inventory provides a basis which guides for the decision making to choose appropriate assessment and monitoring. A Framework for wetland Inventory had to be developed, this Framework furnished the plans and procedure on standard approach for the designing the wetland inventory. Ramsar convention has been providing the handbooks with guidance material with relevant decisions which has to be adopted by the countries recognized as contracting parties. The data in the handbook provides directives as a route map to generate Frameworks in the management activity. For planning and designing a wetland inventory, the steps involved in structured Framework are explained below.

1. State the purpose and objective.
2. Review existing knowledge and information.
3. Review existing inventory methods.
4. Determine the operating scale and its resolution.
5. Establish a core or minimum data set.
6. Establish the classification of the habitat.
7. Selection of appropriate methods.
8. Establish a data management system.
9. Establish a time schedule and the level of resources that are required.
10. The feasibility and cost effectiveness of the project is Assessed.
11. Reporting procedure has to be established.
12. Reviewing and evaluation of the inventory.
13. Plan for the pilot study.

Methods for data acquisition

Depending on the habitat the modification of the framework will be planned. The choice of methods for inventory will regulate the accuracy and precision of details of wetlands and its benefit in the process of planning, conservation and management. The choice of criteria adopted to classify the wetland depending on the similarity in the feature is very important to perform particular tasks. A wrong choice creates nonuniform results in the process of distribution of the space and its vegetation. Hence researcher, scientist and managers and working from many years on wide variations in the approaches for the inventory of wetland ecosystems (Pressey et. Al 1995). The classic methods of the inventory were intense, laborious, involved manual photo- interpretation process, expensive and time consuming (Kloiber et.al 2015). Large scale mapping of the land cover was challenging and even in some cases it was impossible due to required expenditure and available resources for the image analysis. Accumulating huge amounts of data requires more storage systems and data processing was a barrier for creation of land cover maps. Also was the reason for the problem in accuracy and management of the data (Mahdianpari et al. 2020). These complicated conventional surveys have been overshadowed by Satellite remote sensing techniques, where the data from the satellite which is in digital format can easily get integrated into a geographic information system (GIS). It is economical and less laborious in a short period of time than previous aerial photography for large huge geographic areas (Maurer et al. 2002).

Remote sensing

Remote sensing is defined as the science of obtaining information about an area, an object and a phenomenon through the analysis of data acquired by a device which is not in physical contact with the object (Kumar et al., 2003). In wetland inventory, satellites are used to obtain information of the earth surface (Schmidt K et al., 2003). Different sensors of the satellite capture various information of earth cover and its constituents, which is used in inventory, assessment and monitoring of special information. Major satellite systems used to study wetlands are Landsat TM, Landsat MSS and SPOT along with other systems like NOAA, AVHRR, IRS-1B, LISS-II and Radar systems namely JERS-1, ERS-1 and RADARSAT integrated with GIS. Conventional methods used satellite imagery by aerial photography for classification depending on the elevation and topography data. The present technique with the combination Radar and optical data for aerial photography provides high quality geospatial imagery, wetland map databases (Ozesmi et al., 2002). Earlier estimation suggested that the global wetland was around 5.3 to 9.7 km^2 but present investigation shows that the tentative area is minimum of 12.8 km^2 (Finlayson et al. 1999).

Case study examples

China has a wide variety of wetland sites ranked fourth in the world. Over the period of the past 50 decades degradation of the wetland made it necessary to promote sustainable development giving importance to the wetland environment by monitoring the wetland change. Mapping of wetland with multispectral images since 1972 using Systeme Probatoire d'Observation de la Terre(SPOT) (Töyrä and Pietroniro, 2005; Davranche et al., 2013) and Landsat data (Huang et al., 2014, Sader et al). Landsat Thematic Mapper(TM) is used in detection of understory vegetation and freshwater swamps (Congalton et al., 1993;Töyrä et al., 2002). Making multisource data from the Special Sensor Microwave/Imager, which is a radar backscatter from the European Remote Sensing, Advanced Microwave Instrument named scatterometer, visible and near-IR reports from AVHRR, which is the Global Inundation Extent from Multi-Satellites (GIEMS) providing inundation every month (Fluet-Chouinard, 2015), based on which the classification of wetland into lakes, rivers, wetlands, and irrigated agriculture are done. This automatic classification method is called the multi-satellite method (Prigent et al., 2007) to create this database.

Canada wetland inventory CWI implementing remote signalling using the imagery from Landsat, RADARSAT-1 and IKONOS for the classification resulting ISODATA. Dataset and maps created by Canadian National Topographic DataBase (NTDB) using Landsat-7 based on geospatial reference. The maps had a scale of 1:50.00. identified wetland are interpreted in polygon of generic wetlands class. Also make available in layer like topographic contour, and hydrographic network (Fournier et al. 2007). Ramsar wetland convention introduced Synthetic Aperture Radar (SAR). In comparison with the optical sensor used previously would record reflected sunlight, SAR has microwave sensors being insensitive to smoke, clouds and haze will enable to record readings in persistent clouded area. In East central Minnesota(USA) multi- source date obtained is automated for wetland identification using satellite radar imagery, lidar and other GIS data (Koliber et al.,2015). Recently Canada wetland inventory map, a significant increase of 10-m resolution is achieved by using Google Earth Engine (GEE) with reference to optical data (Mahadianpari et al., 2020). Saltmarsh is a complex ecosystem could not be well mapped with optical sensor. Authors Lalit Kumar and Priyakant Sinha were successful in mapping salt marsh in the coastal intertidal area covered sporobolus vegetation from Satellite Quickbird imagery (Kumar et al., 2014).

Wetland Assessment

Wetland Assessment is defined as the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities (Ramsar convention). Mitigation of adverse effects can be done by minimizing the unfavourable environmental effect prior to implementing environmental factors into decision making. Different types of assessment have been designed based on the different situation and intended purpose.

1. Environmental Impact Assessment (EIA)
2. Strategic Environmental Assessment (SEA)
3. Risk Assessment(RA)
4. Vulnerability Assessment (VA)
5. Change in statute and trends Assessment
6. Specie specific Assessment
7. Indicator Assessment
8. Resource Assessment (Ecosystem benefits/services)
9. Assessment of values of wetland benefits/services
10. Environmental water requirement Assessment.

Assessment methods are carried out by different levels and these levels are categorized by Three-tier system or three level system based on intensity and hierarchy (Fennessy et al.,2004).

They are

1. Landscape Level Assessments
2. Rapid Assessments
3. Detailed Assessment

1. Landscape Level Assessments:

wetland assessment conducted in the broader landscape like watershed, county or sub-shed areas. This includes description of the identification of such areas through spatial scales and finding the overview of the type of the vegetation, ecosystem and other features. Remote sensing with the GIS are the appropriate tools for the better understanding of wetland function.

2. Rapid Assessment:

Rapid assessment includes quick collection of Baseline of wetland inventory of marine, inland and coastal biodiversity. This approach depends on the various types of assessment particularly necessary for mitigation of natural disasters like hurricanes, storm surges and tsunamis (Ramsar handbook). Ramsar handbook has provided guidance to Rapid assessment like,

a. Prioritizing inventory of communities and ecosystems for baseline biodiversity information for a given area.
b. Collecting information on the status of target species.
c. Details on effects of human or changes in the nature
d. Gaining details on the general ecosystem health of specific wetland ecosystems.
e. Determining sustainable use of resources in that particular wetland.

3. Detailed Assessment:

Inspect biological, physical and chemical status of wetland ecosystem. Kusler (2006) have mentioned seven groups of detailed assessment models and they are:

a. Detailed field observations.
b. Hydrologic and hydraulic models.
c. Stream hydrologic geomorphic stability.
d. Stream hydrologic geomorphic stability.
e. Index of Biological integrity (IBI).
f. Wetland replacement evaluation procedure.
g. Hydrogeomorphic Approach (HGM).
h. Area wide Assessment.

Among the above mentioned models here is further elaborated discussion on some methods due to their potential application. Hydrogeomorphic(HGM) method comprises the characteristic study of wetland with relation to biogeoche mical, hydrologic and habitat function of watershed area (Gilbert et al.,2006). Hydrologic process refers to duration of water storage on the surface which decides the type of vegetation and living organism and biogeochemical process includes the cycling of nutrients by abiotic and biotic process. In some cases it also involves the study regarding the removal of nutrients, contamination, incorporation of biomass and biochemical reaction. Index of Biological integrity (IBI) is the analysis of biota. The United States Environmental Protection Agency (USEPA) has reported assessment of Amphibians, Algae, birds, invertebrates etc using IBI. This module is designed to get detailed information by sampling methods (Hanson et al., 2008)

Indicator assessment is an important type of assessment, designed to analyse temporal patterns of status and trends in wetland ecosystems and identify the pressure and forthcoming danger. Ramsar convention framed an eight effective indicators namely the status of conservation of wetland, Ramsar sites ecological character status, changes in water quality, Recurrence of threats affecting the sites, implementation and management of plans, population of each taxa and proportion and coverage of various resources.

Case study examples

Bioindicators are the living organisms comprising plants , animals and microorganisms which are used to analyse the fluctuation in the environmental condition. Aquatic plants (Zimmer et al., 2003, frieswyk et al., 2007) . Water birds (Hart et al., 1990), invertebrates and amphibians (Nuria etal, 2011, Michailova et al., 2012), Algae (Palmer 1969) are used as bioindicators. Identification and estimation of microbes is a new trend for the assessment for the environmental changes due to their diverse sophistication to the habitat and known to play a major part in the biogeochemical processes in the ecosystem. They respond quickly and can be easily evaluated by molecular techniques. The ratio of ammonia oxidising archaebacteria and bacterial population has been proposed to function as a microbial indicator to evaluate the wetland nutrient availability(Sims et al., 2013).

Assessment of Functional capacity of wetland conducted in the US based on the evaluation HGM. Functional capacity is the ability of a wetland to function compared with performance of reference standard wetlands. They used three indicators 1. Energy required for short term surface water storage(Brooks et al., 2004), and value was expressed in terms of Functional Capacity Index (FCI). 2. By measuring the removal of imported inorganic nitrogen, where they used soil organic matter SOM as the indicator(Shaffer and Ernst, 1999). 3. Maintaining unique detrital biomass. Here detrital biomass includes dead woody debris, organic debris, they contain necessary organic components for cycling of nutrients (Haueret al., 1998).

Remote sensing techniques provide well timed, up-to-date, and fairly accurate information for Assessment and effective management of wetland vegetation. The vegetation mapping was performed by obtaining multispectral data like Landsat TM and SPOT imagery integration with the Geographic Information System (GIS)(Adam et al., 2010). The wetland biomass estimation done by elucidation of nutrient allocation and carbon cycle(Zheng et al. 2004) and vegetation was determined by reflectance values generated from forest canopy spectral date which correspond with AVHRR, Landsat TM and XMS SPOT sensors (Adam et al., 2009). In the last few decades imagining spectroscopy/ hyperspectral imaging were used in mapping of wetland vegetation (Clark 1999). Glacial basin of Missouri Coteau prairie assessment performed by remote sensing satellite like Landsat ETM over central North Dakota. 89% of accuracy obtained by integrating the natural vegetation and land use with remote sensing technique(Phillips et al., 2005).

Wetland Monitoring

According to Ramsar convention definition Wetland Monitoring determines information for the wetland management purposes in corresponding to the hypothesis obtained from the assessment data and these monitoring results are used for implementation for wetland management.

A systematic technique and procedures has been made to follow the monitoring protocol where various properties of wetland can be observed. Here are some of the properties mentioned below (U.S. Fish and Wildlife Service)

1. Hydrology for Nontidal Wetlands.
2. Hydrology for Tidal Wetlands
3. Hydrophytic Vegetation.
4. Accumulation of Organic Matter.
5. Sediment Accumulation.
6. Salinity for Salt Marsh Restoration
7. Soil Analysis for Created Sites.
8. Wildlife Use.
9. Determining Wetland Extent

The choice of selection of property depends on the type of the wetland which has to be taken care of. Major traditional methods like, sampling and observation of the changes taking place in the different properties of the wetland. This laborious method has been replaced by the new advanced techniques namely Remote sensing. Major satellite systems like Landsat TM, Landsat MSS and others which are mentioned in the inventory and Assessment method are used along with the integration of the GIS.

Case study

Regular mapping of the flooded area change which is beneath natural vegetation was made uncomplicated using Synthetic Aperture Radar (SAR) a remote sensing technique that has been a highly potential tool in surveying. The series of data obtained from RADARSAT-2 FineQuad periodically is evaluated by curvelet- based decomposition of Normalized Kennaugh element and provides polarimetric data to map flooded areas particularly beneath vegetation(Schmitt et. al,. 2013). Interferometric SAR (InSAR) used to estimate the water level changes as a result of climatic change in the eastern Canada having several small wetlands. Any variation in vegetation creates coherence in RADARSAT-2 (coherence change detection CCD) and the data are used to make easily interpretable colour image maps of wetlands (Brisco et al., 2017). The study on land cover change of Ha Tien Plain in Southern Vietnam by deriving Landsat satellite images were fairly low cost, reasonable effort and quick to obtain maps with higher resolution which also facilitated detailed thematic differentiation among land cover types in that particular region(Funkenberg et al., 2014). The San Rossore Natural park of Italy coastal zone monitored by hyperspectral imaging sensors to retrieve biogeochemical parameters and analyse shallow water, moor and dunes with high spatial and spectral resolution(Barducci et al., 2009).

Methane, not only being one of the major pollutants contributes about 20% to 40% of global methane emitted, can also be used in determining the wetland fraction and information about its dynamics in large areas. Earth observation data obtained by ENVISAT ASAR WS used in estimation of methane gas released from land surface and for classifying type of wetlands(Reschke et. al, 2012). A low power wireless sensor networks WSN constituting radio sensor and MICA microprocessor network measure the chromophore dissolved organic matter(CDOM), precipitation, water level and many more conditions of forest peatland(Watras et al., 2014)

CONCLUSION

Different programmes and various methodologies has been adopted by organizations for the wetland management, which completely depends on the severity of extinction of wetland resources. The advanced methods of wetland management like Remote sensing replacing the classic way of has made the Inventory, Assessment and Monitory accurate, less time consuming.

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