Journal of Earth Science & Climatic Change
Review Article Open Access

The Role of Eco-hydrology Approaches in Agricultural Sustainability Improvements and Climate Change Mitigation

Daba Etana*
Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center

Abstract

Increasing current crop production and productivity is the last option to feed the world population may reach 10 billion in with next maximum of twenty five years. The African developing countries estimated to reach around two billion. Currently, around eight million people of sub Saharan African countries fail under malnourished. However, the general goals of world food security double current production and innovate appropriate climate change adaptation technologies. The disturbances of natural system of food chain and complexes under the ecosystem are the most challenge in to achieve the world food security objective. More, the correlations among disturbed natural system and climate change threaten to the current existed life and next generation if not interferences of correction. Majorities of the world class categorized good in productive and well in economy at northern and southern pole are under fear of the increasing of sea currency due to ice melting, LALINA, while tropical countries are under the stress of rainfall, ELLINO and water table shortages. All this needs special focus to develop adaptation technologies emerging from union of different disciplines. Eco-hydrology is one of the departments initiated from several departments focused on ecology and hydrology. Developing suitable mutuality system of organic and inorganic in ecosystem with water body is crucial for this century. About 70 to 75% of this planet is covered by water body. It covers tremendous advantages and disadvantages immersed in water bodies. Thus any life cannot exist and smoothly continue without optimum water requirement for surviving. Finally, maintaining water bodies with its constituents and dry land ecosystem is the most important, basic, and only way to achieve crop production improvements with sustainable production under eco-hydrology.

Keywords: Eco-hydrology; Hydrology; Ecology; Terrestrial

Introduction

The idea of eco-hydrology was initially reported in the end of 20th century. It is considered most valuable into give the past, current, and future use of hydrological, soil and vegetation resources relation and synergisms in arid zones [1]. Eco-hydrology is a new cross discipline that provides comprehensive of novel ideas and approaches to the evaluation of the interactions and feedback mechanisms involved in the soil–vegetation systems. The field of Eco-hydrology is providing new theoretical frameworks and methodological approaches for understanding the complex interactions between vegetation and hydrologic flows and give feedbacks at multiple scales [2]. More, its most useful approach for appraise the ecological mechanisms of water-cycling and resources management in natural sustainability. It is partition to examine and promoted the way of water-soil vegetation system involved into improve agricultural products [3].

Ecoh-ydrology is derived from mixed two independent terms to describe single objective. That is the relationship between hydrology and ecologies, but never separated it means formed hybridizing with each other. The central idea of eco hydrology is to investigate the role of ecology with water relations focusing on plants because it's occupy huge and key components of the hydrologic cycle [4]. It is an application driven interdisciplinary and aims at a better understanding of hydrological factors determining the natural development of wet ecosystems, especially in regard of their functional value for nature protection and restoration [5].

The discipline of Eco-hydrology is rapidly diversified and accepted over the world since the last two decades. Eco-hydrology has rapidly advanced and showed conceptual developments. This is because the influences of artificial factors which deteriorate natural systems dramatically increased due to several factors such as over population, less advancement of technologies in developing countries such as sup Saharan Africa, less extension services.

The two major sources of life in this planet are plants and water. On the other hand, we know that around 74 % of plants are living in the water and need water to survive, the distribution, and composition. The water body is constituents of the structures of plant communities which directly or indirectly influenced by spatiotemporal patterns of water availability [4].

The concept of Eco-hydrology was initiated after global water status, and correlation with arable land is under threatened to sustainable life, specifically agricultural production system. The climate change affected simultaneously by increasing water body through melting ices, and reduces water table especially at marginal area. As a result, future generation needs especial attention to overcome such dilemma through multi-disciplinary under the same umbrella. The declining global water supply and quality combined with the recognized relationship between land use change and water resources is one of the major offering the idea of eco hydrology [6].

Eco-hydrology is potential to address these pressing environmental issues related with water bodies and its importance with dry land activities [7]. The two pillars which needed improvements or at least

***Corresponding author:** Daba Etana, Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, Ethiopia, E-mail: dabaetana2018@gmail.com

Received: 02-Nov-2022, Manuscript No. jescc-22-78187; **Editor assigned:** 04-Nov-2022, PreQC No. jescc-22-78187 (PQ); **Reviewed:** 18-Nov-2022, QC No. jescc-22-78187; **Revised:** 23-Nov-2022, Manuscript No. jescc-22-78187 (R); **Published:** 30-Nov-2022, DOI: 10.4172/2157-7617.1000649

Citation: Etana D (2022) The Role of Eco-hydrology Approaches in Agricultural Sustainability Improvements and Climate Change Mitigation. J Earth Sci Clim Change, 13: 649.

continue with current status in agricultural production are water and arid phase community. Thus, the issue of sustainable life is the agenda of the most executive authority governments, scientists and all stake holders. Therefore, Eco hydrology is generated from the point of sustainability to thrive on this earth.

For instance, in September 2015, the 193 countries of the United Nations agreed to the 2030 Agenda of sustainability which has several goals at 2030, majorly focused on water and sustainable agricultural production and productivity. The issue of Eco-hydrology is considered in sustainable development goal (SDG) with general titles of "Ensure availability and sustainable management of water and sanitation for all" specifically focused in protecting and restoring water related ecosystems. The 6th conference of International Multidisciplinary Conference on Hydrology and Ecology (IMCHE, 2017) focused on how to create awareness and trained with the targets enables wise water resource management in support of other goals related to more healthy lives and sustainable economic development.

Several activities in Eco-hydrology to date focused on understanding the ecology-hydrology-human interactions influencing changing aquatic and terrestrial environments. The nutrient aspect in the hydrology, biological and other environmental sciences alerted in this subject [8]. The integrative approach, expressed by Eco-hydrology principles, should be helpful to distillate or concentrate the general patterns of ecological hydrological interplays, which confronted with social challenges should provide framework for formulation of realistic strategies for problem solving .

Eco-hydrology is more focuses the environmental issues, buffering areas, forest area, ocean, sea and ice parts of the earth, and balancing elements theoretically and practically included. Thus, currently several countries are following the strategies of Eco-hydrology benefited in rural and urban areas, through observed tremendous changes in environmental conservation and reduced vulnerability to occurred risks. This all revealed through sustainability of natural balanced environments and economic development through integration of required corners. So, this review is focused on the role of Eco-hydrology in agricultural crop sustainability with the objectives of describing Eco-hydrology definition, and how to make plays its role in crop production sustainability.

Terminology definition of Eco hydrology

The terms of Eco-hydrology is derived from Greek word oikos means "house or hold", hydro means "water" and logia is an interdisciplinary scientific field studying the interactions between water and ecological systems [9]. Eco-hydrology is considered as branch of hydrology and majorly focuses interaction with ecologies. The major interactions places take place at water bodies, such as river, lakes, wet land, and terrestrial or on land, in forests, deserts, and other ecosystems.

The initial idea of eco hydrology was started in 1990 with the agreement of twenty. More or less, eco-hydrology is included multi-disciplinary with combination of two broad words and defined as single work. The Ecology, hydrology, ecosystem, natural resource management, soil chemistry, Water physics, and chemistry are major subject directly related with eco-hydrology. The narrow definition of eco-hydrology is the area of formal study supported by sciences in ecology and hydrology integration (William, 2021). Thus, it is research investigates the effects of hydrological processes on the distribution, structure, and function of ecosystems, and on the effects of biotic processes on elements of the water cycle.

Majorities of authors reported eco-hydrology as an interaction among wet land, vegetation, biotic and abiotic in the process of surviving and arbitrarily moving way, while some of them as the mutual managements among dry land and water and water bodies. Eco-hydrology is formulation, testing, and application of conceptual models describing the full range of water-mediated interactions between the biotic components of ecosystems and the abiotic environment [10] defined as new paradigm for sustainable management of water resource; it reveals an emerging discipline of study with multiple roots. Hence, Eco-hydrology developed from several models serves as foot to touch the exact required objectives of sustainable development goal in the long and short period plan.

Principles and structures of ecohydrology

The world International Hydrological program (IHP) agreed the importance of eco-hydrology in the current natural disaster maintenance and future sustainability. The broad-spectrum postulation of ecological hydrology is to decrease ecosystem deprivation using concepts that incorporates terrestrial and aquatic processes across scales. The principles of Echo-hydrology is own procedures and order which indicated the way of implements [10]. The major principles are listed below:

1. Hydrological (Framework): The quantification of the hydrological cycle of a basin should be a template for functional integration of hydrological and biological processes. This perspective includes issue of scale, water and temperature dynamics, and hierarchical interactions between biotic and abiotic factors.

2. Ecological (Target): The integrated processes at river basin scale can be steered in such a way as to enhance the basin's carrying capacity and its ecosystem services. This component deals with aspects of ecosystem resilience and resistance.

3. Ecological Engineering (Method): The regulation of hydrological and ecological processes, based on an integrative system approach, is thus a new tool for Integrated Water Basin Management. This method integrates the hydrological framework and ecological targets to improve water quality and ecosystem services, using engineering methods such as levees, bio manipulation, reforestation, and other management strategies.

The hypothesis form of the principles may be seen as triangle of H1, H2 and H3 as listed below:

- H1: Hydrological processes generally regulate biota
- H2: Biota can be shaped as a tool to regulate hydrological processes
- H3: These two types of regulations (H1&H2) can be integrated with hydro-technical infrastructure to achieve sustainable water and ecosystem services

Ecohydrology in natural sustainability

The idea speculation and implementations of Eco-hydrology has been developed in the framework of International Hydrological Program of UNESCO [11]. The major objectives of eco-hydrology are directly or indirectly confirming natural sustainability. Natural sustainability is more or less focuses on the mutuals, commensalisms, and determinants of hydrology and ecosystem. Eco-hydrology focuses on ecological processes occurring within the hydrological cycle and strives to utilize processes for enhancing environmental sustainability [10].

It is mainly focuses in reversing degradation of water resources and environment towards enhancement of ecosystem services for society. It is because sustainability in conditions of the increasing demographic pressures becomes the achievable goal by addressing regulation of the whole range of water biota interactions from molecular to landscape [12]. More or less it pickup scale towards enhancement of carrying capacity in water resources, biodiversity, and ecosystem services for the users.

As far as a primary cumulative indicator of human well-being and the scenario for sustainable future biodiversity are concerned, we have to define what the major drivers determining global biological biodiversity and productivity are. It is well known that water availability determines production [13] and that the increase of biomass is highly correlated with solar radiation. Following these dependencies, the hypothesis introduced by [14] suggests that in the given geomorphological conditions water and temperature are the major determinants of biodiversity (Figure 1). Majorities of soil biota diversification such as microorganisms, and plant and larger animal's species, persistence of favorable mutation, and consequently, the natural selection and adaptation processes become orders of magnitude more favorable areas while, an area where not option for suitability for dwell in organisms develop adaptation mechanisms [14]. Additionally, in human population may also influenced by favorable climate parameters for thrives. For instance, the quantity of human on monsoon land is more condense than other arid areas. Therefore, naturally and man-made disaster on natural balance need recovering, calibrating and feedback and status of the improvements. More, the issues of water in quantities and qualities, temperature rising is headache of the nature in contrary of overpopulation which needs double of current production after fifteen to thirty years.

The linkage of hydrology and ecology is created more opportunities and disadvantage. Around 70% countries populations living in the city and migrating to the city [15]. The city by products contributed around 75% of greenhouse gas emission which causes environmental degradation through resource consumption. Due to these problems, around the city and water bodies special attention given and remediation activities under conducting in developed and some of developing countries. Thus, the idea of "cities are both the problems and solutions to sustainability challenges of an increasingly urbanized world" [16]. Rees and Wackernagel, (1996) reported that the way to achieve the resilience of a climate change would rely on the management of ecology, hydrology and their interactions.

Each of the eco-hydrology disciplines followed their approach to achieve the sustainability among each other's. However, all approaches synergy and support each other's. For instance, innovation technologies in remediation of water and water bodies considered the issues of land degradation. The issues of land degradation considered how to conserve, increase carbon sequestration, and mitigate the impacts of climate change. Therefore, the all approaches are used as the piling of the eco-hydrology objectives.

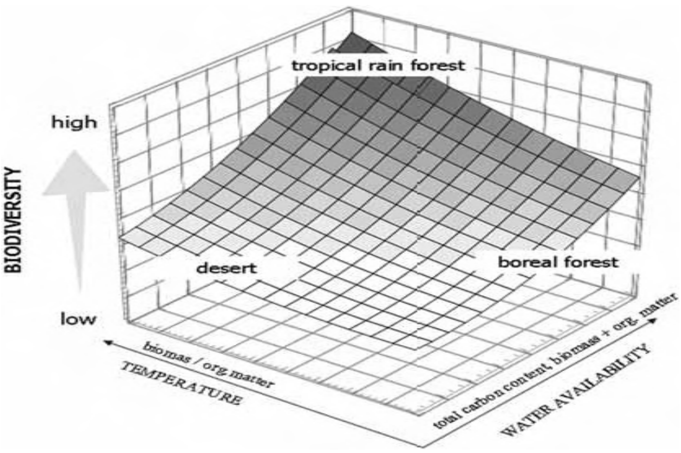

Figure 1: The general distributions of global biodiversity (Zalewski, 2002b).

Major Eco hydrological Approaches

Eco-hydrology is providing new theoretical frameworks and methodological approaches for understanding the complex interactions and feedbacks between terrestrial organisms including vegetation and hydrologic flows at multiple scales [17]. It is focused in integration of socioeconomic and cultural considerations into the process enhance the dynamic relationships between hydrological, social and ecological systems. For instance, Netherlands has its roots in three lines of scientific research approaches in the Eco-hydrology [18]. The wider approach focuses in vegetation science, hydrology of mire ecosystems and agro-ecological research on soil fertility. Based on the most important and preferable effects, eco hydrological approaches should be discussed classified in to three approaches.

Vegetation science approaches

Water constituents in plant tissues around 70%, and turgid the tissues under normal condition. Nonetheless, water is considered as non-living or has no soul; it is the prominent and determines surviving of primary, secondary and other producers. Soil moisture is the key abiotic limiting factor in plant life and hydrological processes determine the vegetation composition, patterns and processes [10]. All types of plants on the world had have been the own impacts on the eco hydrology. Water dynamics always described as the principal topics of vegetation construction [19]. It has capacity to define the processes of sustainable development of the vegetation and the stability of the system.

The mechanisms of vegetation-regulation and soil development with appropriate plants rise as crucial activities in vegetation approach in evaluation of water circulation normality. Eco hydrological research usually does not claim to unruffled all hydrological and ecological mechanisms responsible for the observed changes in the species composition of damaged or restored wetlands, but it may contribute to the understanding of how to properly manage these ecosystems. The remediation activities held under the eco-hydrology is responsible for positive change will happen in the study area. For instance an area where annual rain fall is less than 200 mm in deserted area, the soil water content (within 0–3 m) rehabilitated after re-vegetation for 10 years after re-vegetation with water table increment by 3–3.5 percent. More, after re-vegetation of dry land (desert) for consequently 40 years, the surface soil's water-holding capacity increased to 80 percent, and available water content increased, which was closely correlated with distribution of rainfall; mean-while, soil water content decreased in the deeper horizons (from 4-5 percent to 1 percent) and failed to be correlated with the distribution of rainfall. As the result, the subordination among hydrology and vegetation and their interaction has valuable in environmental remediation.

Sometimes, a plant changes their pioneer to get adaption capacity. For instance, Li et al. (2004b) reported the vegetation changed from xerophytic shrubs to cryptogams (cyanobacteria, desert alga, lichen and moss species), annual herbs, and a shallow-rooted sub-shrub species. These changes in vegetation have created favorable conditions for the establishment and reproduction of many other species, which has promoted the succession of decertified areas. This improvement indicated that the water-use efficiency increases entire vegetation system [20].

The vegetation approaches encompass terrestrial and aquatic phase of the hydrological cycle include rainfall. The symptoms observed on the phase of different biota serve as indicators of water dynamics. For instance, at above earth dry land (terrestrial) phase, vegetation moderates water quality and quantity [10]. The simulation models of vegetation approaches under hydrological cycle in different land coverage's which may influences described in Figure 2. Thus, the cycle of Eco-hydrology was highly influenced by natural and anthropological modified land coverage and they are directly related within each other's.

Aquatic approach

Aquatic or water body is the greatest ecosystems of earths which influenced by different sources and users such as; evapotranspiration, precipitation, infiltration, retention, sub surface run off, total runoff, surface run and underground run off (Figure 3). Factors of aquatic controlled the aquatic system and surviving chain in all organisms. The other is that problems of water cycle, quality were solved through controlling and study all factors of aquatic body through eco-hydrological approaches. This approach focuses on the design how aquatic factors smoothly moving with no or illegible disturbances.

More or less water body is encompasses from xerophytic to angiosperm large plants. In the aquatic phase, complicated biotic interactions determine water quality, related symptoms of eutrophication (e.g., algal blooms) and bio magnifications in the food chains of heavy metals, and persistent of organic pollutants. The density of plant species usually follows aquatic contents, direction and quantity.

Movement of stream water, discharge of groundwater from aquifers

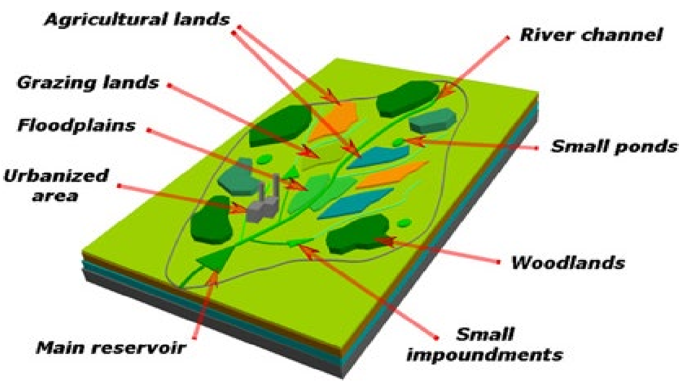

Figure 2: Distribution of various types of vegetation and water cycles (Zalewski 2010).

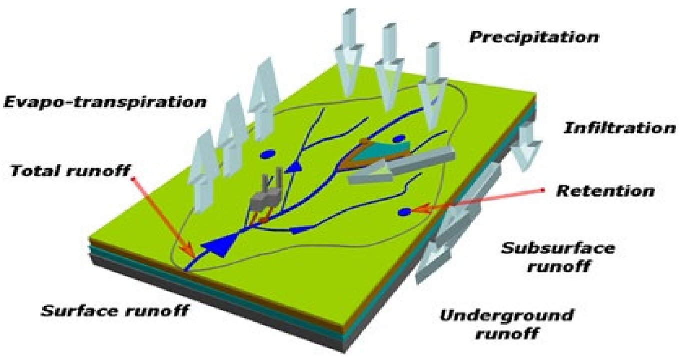

Figure 3: Auatic factors designing structures (Zalewski, 2010).

and infiltration of precipitation water, each have specific impact on the site characteristics of wet ecosystems since they contribute differently to the specific ionic composition of a wetland site. Diversity in ionic composition in the wetlands mainly depends on the origin of the water. Interferences in the hydrological cycle affect both the fluxes and the ionic composition of water flows. This in turn triggers changes in site conditions which lead to succession.

An aquatic approach of Eco-hydrology has also focused the relationships between water and animals in the water bodies. [20] Reported the animal contents improvements of water bodies fish contents after protection by twenty percent's. Additionally the quality of water and aquatic bodies highly influenced on anthropological healthy. Thus, the water bodies were influenced by different things and follow its own cycle.

Soil - fertility approach

The influences of agricultural activities in natural sustainability is most important issues, and impossible to cease agricultural practices at different stages. The impacts of inputs and intensive agricultural movement were the most disturbances eco hydrological balances. Water balance and water circulation are always chief topics agricultural practices, because these processes define the sustainable development of agricultural practices, and the stability of the system.

Intensive agriculture promoted all over the world through scientifically less effects on the soil fertility and high risk without conservation practices in majorities of developing countries. This, adversely damage eco-hydrology and disturb wild and domestic animals, soil flora and fauna, and human being itself due to the bank of nutrients and resources. Deforestation most frequently reported and current world forest is less than 10% which causes weather temperature and rain fall fluctuation all over the world. The low productive bank loose vegetation with endangered 'Red List' species was restricted to sites with low amounts of organic matter and nitrogen in the top soil. It was hypothesized that a regular supply of acid buffering components from the calcareous soil buffers the pH at a circum neutral level and slows down the accumulation of organic matter thus creating opportunities for the rare basiphilous plant species. As described in Figure 4, the influences of both water and ecosystem in the land normality system. Hence, soil serve as back bone into achieve Eco-hydrology objectives.

Plant-soil interactions in soil moisture dynamics

In most ecosystems, plants forms critical pathway for water fluxes between the soil and atmosphere. Lin and Rathbun, (2003) reported water flow and transport processes, variability and mass-energy interactions in the structured and unsaturated soil zone. One area receive increased attention is the relationship between spatiotemporal patterns in water fluxes within the soil profile and the distribution, structure and physiological functions of plant communities.

The amount of water in the soil influenced by several things such as soil nature, aquatic factors, and external vegetation types. The above ground vegetation style shows the depth, amount, and qualities of moisture in the soil through fluxes. This means plants develop tolerate mechanisms of deficit areas and species adaptation tolerance level determines areas of habituation. For instance, mechanisms such as dormant, defilation, small leaf size, reducing stomatal conductance indicated from the listed as tolerate mechanisms. Thus, vegetation can exert reciprocal feedbacks on the vertical and horizontal distribution of plant available water through diverse mechanisms.

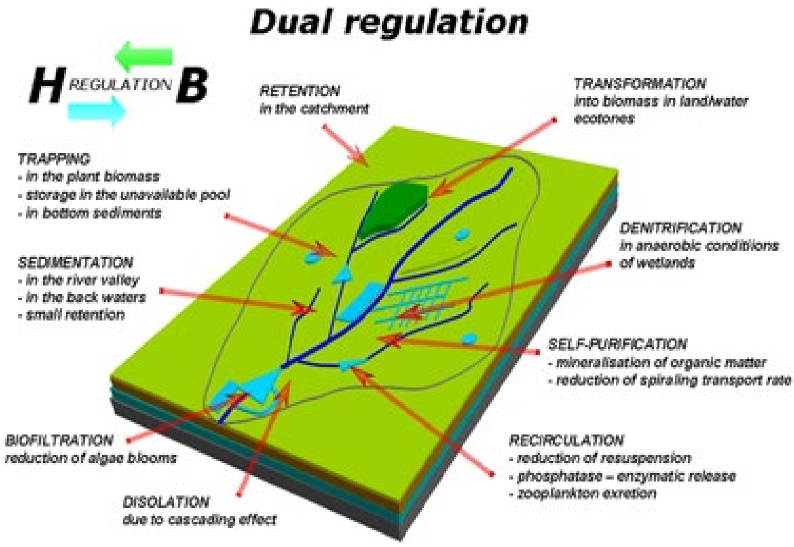

Figure 4: Ecological Engineering – use of biota to control hydrological processes (Zalewski, 2010).

Role of Cross cutting Eco hydrological Approaches

Ecohdrology scholars reported as both terrestrial and aquatic require the unity of different departments under the umbrella of this subject. The solution of the worst and threaten of current and future life climate change will overcome through this "ecosystem properties become management tools to achieve sustainable development" support by mathematical modeling (Jorgensen, 2002). They are crucial to formulate bold hypothesis, which consider multiple trajectories of precisely quantified processes with rigid explicit criteria. All of these hypothesis lead to efficient implementation of catchment scale systemic solutions and help to avoid "trial and error" approach. One of the best principles of ecohydrological provides a framework for its implementation will be developing new modeling technology.

Developing new modeling technology

The next one advance in to develop and have potential to influence move Ecohydrology to implementations is develop appropriate and area specific modeling tools. Some tools under practicing and implementation as advanced new tools in eco hydrological researches, such as integrated simulation models, remote sensing, process-based models, isotopic methods, and eddy flux techniques. Zakharova et al. (2012) retrieved soil moisture and vegetation optical depth (VOD) by analyzing the results of Cooperative Airborne Radiometer for Ocean and Land Studies (CAROLS) air-borne data. The high resolution models still interest for both hydrological and biogeochemical communities. Gao et al. (2012) coupled the modified Soil Conservation Service curve number (SCS-CN) and Revised Universal Soil Loss Equation (RUSLE) models to simulate hydrological effects of restoring vegetation. In addition, the Normalized Difference Vegetation Index (NDVI) also used as model for examine the relationships between vegetation and ecosystem water balance activity (Sun et al., 2012). The others were: Water Erosion Prediction Project (WEPP), Revised Universal Soil Loss Equation (RUSLE), Geo-spatial interface for WEPP (GeoWEPP), Lavras Simulation of Hydrology (LASH), Soil and Water Assessment Tool (SWAT), Distributed Hydrology Soil Vegetation Model (DHSVM), and Annualized Agricultural Non-Point Source (AnnAGNPS) (Mello et al., 2020). However, several climate change simulation models recently developed specific to countries and widely adapted in different agro ecologies. Such technologies providing huge opportunities to forecast the future climate change impacts on the ecosystem and develop mitigation and adaptation technology to intervene the problems under the umbrella of ecohydroloy.

Summary

Ecohydrology is the multi disciplinary which studying about intensively the influences of ecology on hydrology and vice versa. Based on its importance's, considerable scientists and governmental authorities so far worked on these sciences. As a result, a change exists as idea and knowledge levels with different level of understanding it are role in life sustaining, especially in developed countries. Scientists received consciousness as ecohydrology is the heart of soil and water conservation due to the world taken as the most crucial factor capacity to change the face of this earth and against direct to climate change and its cofactors.

Even though ecohydrology has capacity to influences of on the terrestrial and aquatic body in to connect in every of life cycle, the level of formal study and understanding is need special attention in developing countries such as Ethiopia. Huge capacity, recourses and opportunity existed, while due to less information how to boll out and using techniques, still dispatched and need train users and applier at different levels. To maintain this, the role of ecohydrology on the way of understanding and behind that highly works on protecting, preventing, and controlling eco hydrological risk is the most and solution for unbalanced natural system and mineral nutrient in soil with in social inter action relationships. Finally, if collaboration works on the elements of ecohydrology stakeholders, at different levels, the efficiency of resource uses and mitigation and adaptation potential improved at different levels of involvers.

References

1. Cosimo Solidoro, Vinko Bandelj, Fabrizio Aubry Bernardi (2010) Response of the Venice Lagoon Ecosystem to Natural and Anthropogenic Pressures over the Last 50 Years. Coastal Lagoon: Environ Sci 483-512.

2. Chacko PI, Abraham JG, Anda1 R (1953) Report on a Survey of the Flora, Fauna, and Fisheries of the Pulicat Lagoon, Madras State, India, 1951-52. Contribution from the Freshwater Fisheries Biological Station. Madras 8.

3. Zhao RF, Chen YL, Shi PJ (2013) Land use and land cover change and driving mechanism in the arid inland river basin: a case study of Tarim River, Xinjiang. J Environ Sci (China) 68:591-604.

4. Ramesh R (2003) No impact zone studies in critical habitats: Pulicat lagoon

ecosystem. Annual Report submitted to ICMAM - PD, Department of Ocean Development, Government of India, and New Delhi 200.

5. Ramesh R, Purvaja R, Ramesh S, James RA (2002) Historical pollution trends in coastal environments of India. Environ Monit Assess 79:151-176.
6. Natesan U, Rajalakshmi PR, Vincent A Ferrer (2014) Shoreline dynamics and littoral transport around the tidal inlet at Pulicat, southeast coast of India. Continental Shelf Research 80(1):49-56.
7. Yashon O. Ouma, Tateishi RA (2006) Water Index for Rapid Mapping of Shoreline Changes of Five East African Rift Valley Lakes: an Empirical Analysis using Landsat TM and ETM+ Data. Int J Remote Sens 27(15):3153-3181.
8. Gupta A, Asher MG (1998) Environment and the developing world: principles, policies, management. Wiley 370-376.
9. Ramasastry AA, De US, Vaidya D, Sundari G (1986) Forty-day mode and medium range forecasting. Mausam 37(3):305-312.
10. Bianrong Chang, Rendong Li, Chuandong Zhu, Kequn Liu (2015) Quantitative Impacts of Climate Change and Human Activities on Water-Surface Area Variations from the 1990s to 2013 in Honghu Lake, China. Water 7(6):2881-2899.
11. Cosimo Solidoro, Vinko Bandelj, Fabrizio Aubry Bernardi, Elisa Camatti (2010) Response of the Venice Lagoon Ecosystem to Natural and Anthropogenic Pressures over the Last 50 Years. Coastal Lagoon: Environ Sci 483-512.
12. Gupta H (2005) Mega-Tsunami of 26th December 2004: Indian initiative for early warning system and mitigation of oceanographic hazards. Episodes 28(1):4.
13. Prabhakar KN, Zutshi PL (1993) Evolution of southern part of Indian east coast basins. J Geol Soc India 41:215-230.
14. Das N, Desai DS, Biswas NC (1989) Cyclones and depressions over the Indian seas and the Indian sub-continent during 1987. Mausam 40(l):1-12.
15. Chacko PI, Abraham JG, Anda1 R (1953) Report on a Survey of the Flora, Fauna, and Fisheries of the Pulicat Lagoon, Madras State, India, 1951-52. Contribution from the Freshwater Fisheries Biological Station. Madras 8.
16. Sanjeeva Raj PJ (2006) Macro fauna of Pulicat lagoon, NBA Bulletin No.6. National Biodiversity Authority. Chennai 67.
17. Zhao RF, Chen YL, Shi PJ, Zhang LH (2013) Land use and land cover change and driving mechanism in the arid inland river basin: a case study of Tarim River, Xinjiang. J Environ Sci (China) 68:591-604.
18. Yashon O. Ouma, Tateishi RA (2006) Water Index for Rapid Mapping of Shoreline Changes of Five East African Rift Valley Lakes: an Empirical Analysis using Landsat TM and ETM+ Data. Int J Remote Sens 27(15):3153-3181.
19. Ramesh R, Purvaja R, Ramesh S, James RA (2002) Historical pollution trends in coastal environments of India. Environ Monit Assess 79:151-176.
20. Natesan U, Rajalakshmi PR, Vincent A Ferrer (2014) Shoreline dynamics and littoral transport around the tidal inlet at Pulicat, southeast coast of India. Cont She Res 80(1):49-56.