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Strategic Management of Wetlands within DPSER Framework: A Case Study at Cheleleka Wetland, Rift Valley Lakes Basin, Ethiopia

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ABSTRACT

In terms of function, wetlands are valued as living machines, nature's kidney, biological supermarkets, and sink of carbon. Quantification of these wetland functions is a powerful tool for informed wetland management decisions since not all wetlands perform all functions nor do they perform equally well. In addition, due to the wide range of issues, wetland management plans need systemic approach that accounts for ecosystem complexity for improved efficacy. By taking Cheleleka Wetland in the Rift Valley Lakes Basin as a case, this paper demonstrated the application of Drivers-Pressures-State-Ecosystem services-Responses (DPSER) framework in which the potential ecosystem services (=E) were evaluated by semi-quantitative method based on field indicators; hydrologic cycle simulation using soil and water assessment tool; and inventory of water abstraction (=P). Results indicated that the wetland is potentially performing ≈77% in improving water quality; ≈67% in recharging groundwater; ≈60% in providing biological support; and ≈40% in reducing flood peak. Anthropogenic hydrologic pressure in terms of water abstraction approximates ≈43% of the recharged volume. As response (=R) strategy, four synergetic wetland management approaches were formulated and coined as PREE representing Preservation-Restoration-Enhancement-Establishment interventions. Based on the above strategy, specific local wetland management strategies were also formulated.

Key words: Cheleleka wetland; DPSER; PREE; strategic management

1. Introduction

"Wetland" is the collective term for marshes, swamps, bogs, and similar areas (Ramachandra 2001). Maltby (1986) coined the term as " ecosystems whose formation has been dominated by water and whose processes and characteristics are largely controlled by water" while Cowardin et al. (1979) defined it as "lands of transition between terrestrial and aquatic systems where the water table is usually at or near the surface of the land or the land is covered by shallow water". Although the value of wetlands for fish and wildlife protection has been known for a century, some of the other benefits have been identified more recently (Mitsch and Gosselink 2015). Wetland functions are in most cases insufficiently appreciated and rarely recognized by most people and only to a limited extent quantified (Ostrovskaya et al. 2013). However, not all wetlands perform all functions nor do they perform all functions equally well. Many factors determine how well a wetland will perform these functions (Novitzki et al. 1997). Wetlands are fragile ecosystems that are susceptible to changes even with little change to the composition of their biotic and abiotic factors. They are least understood and most abused assets (Maltby, 1990); endangered ecosystems (Ramachandra, 2001); routinely overlooked (McInnes, 2013); underestimated (Turner et al. 2008); continually declining both in area and in quality (Seid, 2017); under increasing anthropogenic pressure (Gebresllassie et al., 2014;); and degraded beyond the socially optimal extent (Turpie et al., 2010).

As evidenced by Junk et al. (2013), 30-90 % of the world's wetlands have already been destroyed or strongly modified resulting in more than US$ 20 trillion losses of ecosystem services annually (Gardner et al., 2015). The situation is likely more complex in developing countries. Their loss or impairment is usually accompanied by irreversible loss in both the valuable environmental functions and amenities important to the society (Zentner 1988).

Wetland management is a relatively new field (Euliss et al. 2008) and needs to be holistic as well as systematic to give structure to the planning process and encourage a logical approach while considering wide range of issues (Chatterjee et al. 2008). A holistic approach that accounts for ecosystem complexity and integration rather than managing for individual issues improves efficacy of management efforts (Slocombe 1993). The list of environmental issues in relation to wetland management has been growing and their inter-linkages with their complex causes and consequences are getting complex. To tell an integrated story of these issues, the need of structured process (framework) that can accommodate interdisciplinary knowledge is of a paramount importance (UNEP 2008). The traditional DPSIR (Driver-Pressure-State-Impact-Response) framework is considered as the best way to structure such environmental information in order to build links between natural and socio-economic sciences; science and management; qualitative and quantitative analyses; measured and modeled data; and definition of environmental syndromes (Turner et al. 1998). As a drawback, a number of researchers noted that the DPSIR model omitted the ecosystem services (Atkins et al. 2011) which denotes the benefits that people obtain from ecosystems (MEA 2005) and consider only the negative environmental consequence of human activities in its 'impact' term (Bowen and Riley 2003). In order to overcome this deficit, its new version called DPSER (Kelble et al. 2013) was evolved by replacing impacts module with ecosystem services module. Incorporating this concept into the DPSIR assessment framework makes it more broadly applicable (Chicharo et al. 2015)

Despite their broad application in environmental assessments, DPSIR and its derivative DPSER have not been commonly used in supporting wetland management programs. This research aimed at applying the DPSER model in order to synthesize the available and gegenrated scientific facts about the wetland system by taking Cheleleka wetland in the Ethiopian Rift Valley Basin as a case to demonstrate utility and versatility merits of the model in the management of natural wetlands.

2. Material and methods

2.1. Area description

As shown in Figure 1, Cheleleka wetland is located in the upstream of Lake Hawassa in the Ethiopian Rift Valley Basin within the coordinates of 447,290m and 453,980m (Easting) and 774,465m and 785,800m (Northing). Based on the wetland delineation procedure, its size is about 34 km^2 (Belete 2018) and size of the catchment is about 645 km^2.

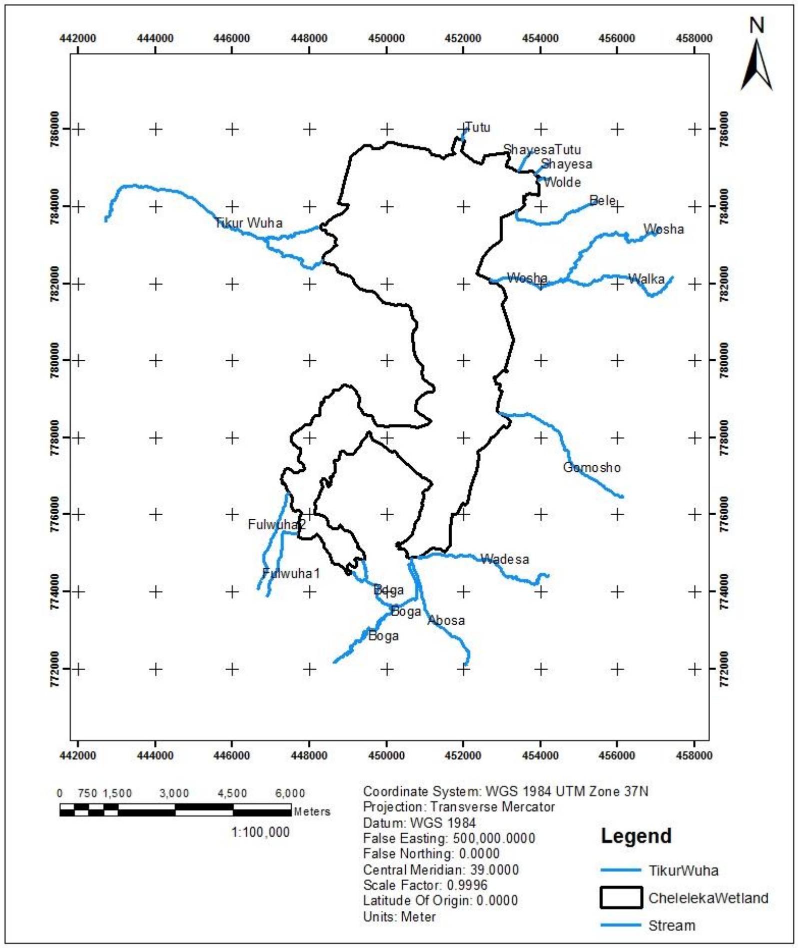


Figure 1. Location of the study area

Cheleleka wetland qualifies as riverine flow-through type wetland with predominant hydrophytic vegetation types found in the study wetland are *Typha* (cattail), which is emergent and herbaceous, and *Nymphaea odorata* (water lily) which is of the floating-leaved type (Belete 2018). In the nineteenth century, Lake Hawassa and Cheleleka Wetland had been a single lake (Grove et al. 1975) and Lake Cheleleka was serving as a natural regulator of flow, sedimentation, and biogeochemistry for Lake Hawassa.

2.2. DPSER framework

As shown in Figure 2, Driver-Pressures-State-Ecosystem services-Responses (DPSIR/DPSER) model (OECD 1993) is a conceptual framework in which Drivers and Pressures describe factors that cause change in the condition of the ecosystem. State describes the environment in terms of attributes that relate to Ecosystem Services. The Response element of the framework describes decisions and actions people take to sustain or increase the ecosystem services they value.

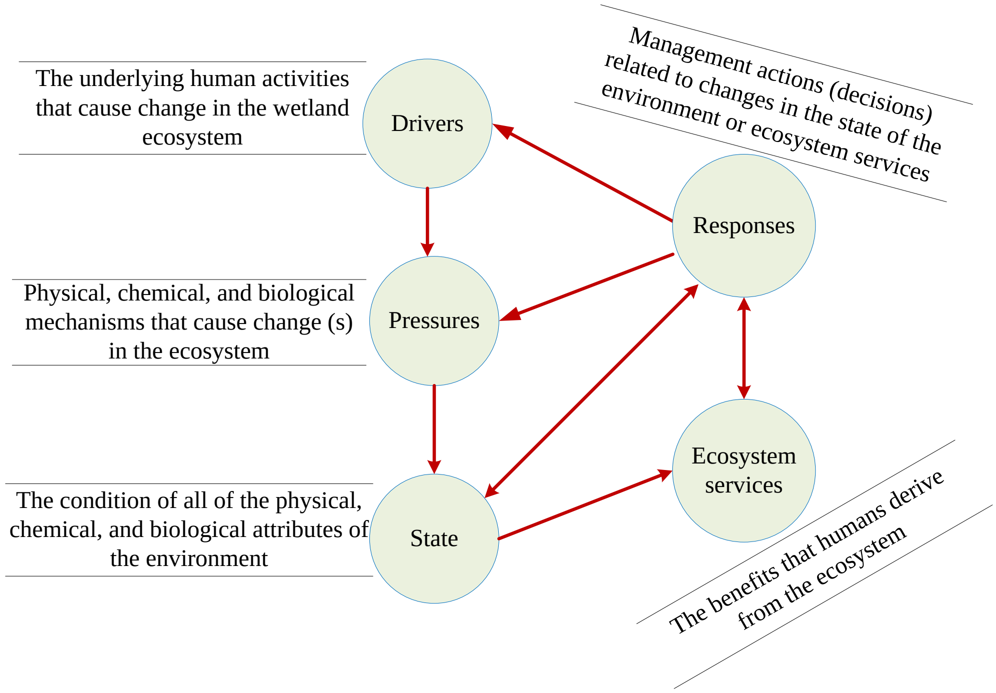


Figure 2. The DPSER framework in a decisional context

2.3. Semi-quantitative approach to assess the potential ecosystem services/wetland function

Potschin and Haines-Young (2016) defined the ecosystem services as 'the direct and indirect contributions of ecosystems to human well-being'. The concept of ecosystem services has rapidly become the dominant approach to understanding and prioritizing the natural world for conservation and development decisions (McElwee 2017). Despite this, there is no standard metric to measure it (Danley and Camilla 2016) and the same happens to wetland ecosystems or their natural functions. However Leibowitz et al. (1992) used Synoptic Approach to assess natural functions/ecosystem services delivered by wetlands; Smith et al. (1995) applies Hydrogeomorphic Method (HGM); Karr (1981) used the Index of Biotic Integrity (IBI); Miller and Gunsalus (1999) employed the Wetland Rapid Assessment Procedure (WRAP); USACE (1995) used the Descriptive Approach; USFWS (1980) applied the Habitat Evaluation Procedure (HEP); Zampella et al. (1994) also used the New Jersey Watershed Method ; and Collins et al. (1998) applied the Watershed Science Approach. Generally, there is not yet a generally accepted approach to measure the complete bundle of ecosystem services provided by an area (Reyers et al. 2014).

This research employed Semi-quantitative Assessment Methodology (SAM) of Cooke Scientific Services (2002) to evaluate current performance of the four key wetland function/ecosystem services: potential to improve water quality; to recharge groundwater; to reduce flood peak, and to provide biological support to fauna and flora. The method is employed for two reasons. First, due to its simplicity and, second to benefit from previous result of Belete (2018). This study extended this study to include the biological support (habitat) function of the wetland using the Semi-quantitative Assessment Methodology. *Table 1* shows the field indicators and the corresponding scoring criteria.

Table 1. Field indicators to assess the habitat function of the wetland using SAM method

	Indicators	Assessment method	Criteria of scoring
1	Connectivity	Standard method of 8m x7m rectangular quadrat	3pt=high if >60% vegetated; 2pt if 20-55% vegetated ;1pt=low if only <20% vegetated
2	Vegetation structure	7m x8m quadrat was laid alternatively at 0, 20 and 40m of the transect	3pt=high mosaic of many community; 2pt=moderate if 30% two canopy layer 1pt= low only one layer 90%
3	Surface water presence	5m x 5m quadrat laid alternatively on transect line	3pt if >30% permanent open water in pool; 2pt if >30% permanent surface water in stream ; 1pt if >30% seasonal surface water
4	Community type	10m x 5m rectangular quadrat laid alternatively on transect line	3pt if three or more habitat type >30%; 2pt if two habitat type > 30%; 1pt if one habitat type 30%
5	Plant diversity	5m x 5m quadrat laid alternatively on transect line	3pt if >15 species; 2pt if 7-15 species; 1 pt if <7 species
6	Invasive species	>>	3pt if <10% cover ; 2pt if 10-50%; 1pt if >50%
7	Organic accumulation	Random sampling inside the quadrat at depth of 15cm	3pt=high soil predominantly peat deposit ; 2pt= moderate predominantly organic 1pt=low predominantly mineral
8	Organic export	Observation of speed of water in the 5m x5m quadrat laid alternatively on transect line	3pt=high productivity & high water flow ; 2pt= moderate productivity & flow; 1pt= slow productivity & flow
9	Habitat features	5m x5m quadrat laid alternatively on transect line	Existence of logs, snags, perches. 3p= exist as many ; 2pt= as some ;1pt=as few 0 = not exist
10	Buffer condition	Estimate the area busing 60m transect line perpendicular to the wetland	Status of disturbance : 3pt if < 20% lightly disturbed; 2pt if 20-60% moderate 1pt if >60% high
11	Connection to upland	5m x5m quadrat laid alternatively on transect line	3pt if >60% well connected; 2pt if 20-60% partially connected ; 1pt if < 20% lightly isolated

2.4. Quantification of water balance and inventory of anthropogenic water abstraction

The overall water balance of the catchment was simulated using Soil and Water Assessment Tool (SWAT) which is a physically based model developed in 1990s. Specific information required for SWAT includes weather, hydrology, soil, topography and land use data (Neitsch et al. 2002; Yan et al. 2013). The available data from 1985-2013 were acquired from National Meteorological Agency as input for testing, calibration, and validation purpose. The model simulates the land phase of the hydrological cycle based on the water balance equation (Arnold et al. 1998) as shown in *equation 1*.

$$SW_t = SW_o + \sum_{i=1}^{t}(R_{day} - Q_{sur-}\,E_a - W_{seep} - Q_{gw}) \quad (1)$$

Where:

SW_t = is the final soil water content (mm); SW_o = the initial soil water content; R_{day}= the amount of precipitation; Q_{sur} = the amount of surface runoff; E_a = the amount of evapotranspiration; W_{seep}= the amount of water entering the vadose zone from the soil profile and; Qgw = the amount of return flow on day i (mm); and t = the time (days).

The aim of simulating the water balance in this study is to compare quantities of the hydrologic cycle with the magnitude of anthropogenic water abstraction. For this, water abstract was subjected to real time inventory by considering location of abstraction, magnitude of abstraction, abstracting sectors, and source of water (either surface or ground water).

2.5. Qualitative approach to assess the socio-economic status of the wetland

In order to supplement the above (semi) quantitative methods, qualitative techniques including structured observation, in-depth-interview (with twelve key informant community elders and development workers), and focus group discussions (three segments of the community composed of men and women (with a total of 24 participants) were administered. The focuses of the qualitative techniques were to understand: how the community perceived the wetland system; the socio-economic services delivered by Cheleleka wetland; the prevailing anthropogenic pressures; and to identify the prevailing push-pull factor.

3. Results and discussion

3.1. Performance of the wetland in terms of habitat function based on field indicators

While quantifying potential performance of the habitat function of the wetland based on the eleven field indicators (Figure 3), it is found to have an approximate potential of ≈ 60% . The wetland is positively influenced by its 'hydrologic connectivity' and for its 'less significantly invaded by exotic species'; and negatively influenced due to the low score in 'vegetation structure', 'plant community type', 'plant diversity', and 'habitat features'.

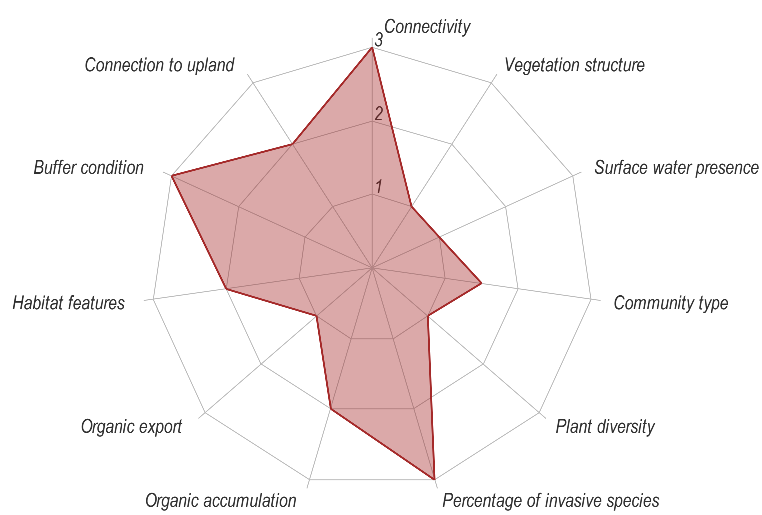


Figure 3. Spider diagram for biological support potential of the wetland

3.2. Results of water balance assessment and its anthropogenic stress in terms of ground water abstraction

While investigating the anthropogenic pressures (=P) through the application of water balance approach (Figure 4), it was found that the wetland catchment has been gaining 1300 mm/yr rainfall and losing 656 mm/yr (through evaporation). In terms of recharge, a magnitude of 118 mm/yr of water leaves the wetland system; similarly 57 mm/yr of water leaves the system through sub-surface. The system gains 461 mm/yr as ground water.

On the contrary, the water abstraction inventory result (*table 2*) indicates that about 177,948,858 m^3 or about 276 mm/yr of water (≈ 43% of the recharged volume) is being anthropogenically abstracted for irrigation, industrial use, water supply, and hotels without any responsibility of ground water recharging and tariffing system in place.

Table 2. Annual volume of water abstraction by sectors (result of water abstraction inventory)

Abstraction sector	Annual abstraction (m^3)	In terms of depth (mm)
Hotels	460,060	Depth equivalent $=\frac{177,948,858\ m^3 *}{645 * 10^6\ m^2} * 1000 \approx \mathbf{276\ mm}$
Factories, industry park and Hawassa University	2,602,704	
Drinking water supply	5,019,465	
Irrigation	169,866,629	
Total	177,948,858	

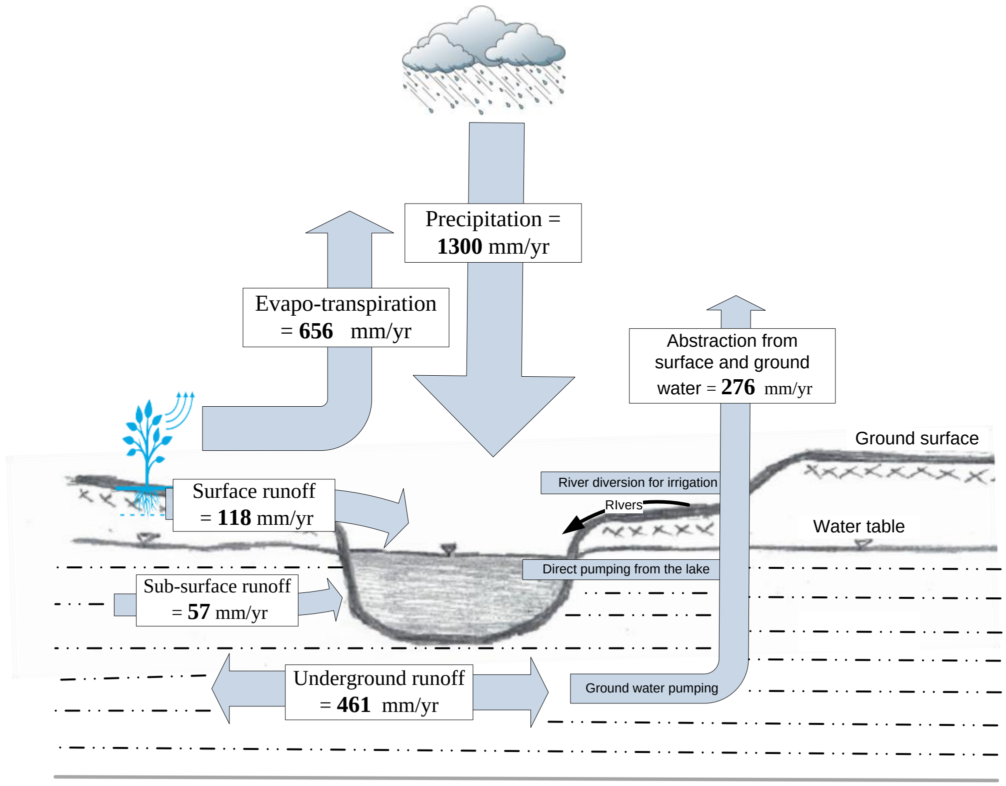


Figure 4. Diagram showing hydrologic cycle in the catchment and water abstraction

3.3. The way the community perceives the wetland system

Community perception and attitude is a major factor in the success of a conservation projects or survival of natural resources (Mogomotsi et al. 2020) that can provide insight into people's behaviors and the extent to which they are willing to coexist with a particular resource (Mir et al. 2015). Results of the focus group discussion and interview of key informants revealed that, the community perceives the wetland as:

- a land occupied by has "*Cheffe*" (local name for big grasses),
- a place where water stagnate during the rainy season and dries out during other time,
- a muddy place that is covered by different species of grasses,
- a land where terrestrial plants cannot grow ,
- a land which is not suitable for farming activities and requires treatment,
- a parcel of land that is owned by all but managed by none.

3.4. Socio-economic services delivered by Cheleleka wetland

The focus group discussion and interview of key informants also revealed the ecosystem services that are perceived by the community that include:

- socio-culturally importance through its hot springs that heals skins diseases,
- the salty water and its extracted salt (locally referred as 'bole') is used for personal hygiene for washing clothes without soap as well as feed for cattle,
- the place is used for habitat for hippopotamus, birds and grasses that use to attract tourists,

- effective site for cattle breeding,
- important source of special grass species that serve as cover for local houses (local name = Hanxo/ Qonce); for grazing animals (local name = Qaqqaba-/ Alumo); for construction of traditional boats and firewoods (local name = *hambena*);

3.5. The observed anthropogenic pressures on the wetland

3.5.1. Expansion of farming practices in the wetland

Following the formal establishment of Shallo seed farm (a government owned farm which holds about 1300 ha), the local farmers cultivate the surrounding which accounts about 10 ha of lands which was part of the wetland.

3.5.2. Hydrologic alterations using bio-drainage

Hydrologic alterations, which include changes in the hydrologic structure and functioning of a wetland by bio-drainage using eucalyptus, de-watering by consumptive use of surface water inflows (using intensive irrigation for cash crop production), unregulated draw down of unconfined aquifer from either groundwater withdrawal by industries for various human activities.

3.5.3. Unregulated settlement patterns

Settlement in the wetland system is found to be linked with political decision with an intention to provide farming lands for unemployed individuals of the community. Following this initiation, unregulated settlements have taken place with a total of over 500 houses. Currently, more than 3000 people reside in the wetland system.

3.5.4. Industrial Effluent

The south western part of the wetland is exposed to industrial effluents from factories operating in the area. These industries have been releasing effluent since their establishment in 1980s. Although several industries such as beverage, soap, textile, plastic, meat processing and many others are operating in the area, it was evident that the brewery factory, has prominently discharged its waste. The community has been suffering from skin irritation and respiratory diseases due to direct contact and pungent smell. Children are affected by the waste, which smells alcohol, while they often use it for swimming during the rainy season. The effluents are perceived as causes of fetal abortion, reduce milk production, discolor milk and emaciate animals.

3.6. Synthesis of the Drivers-Pressures-State-Ecosystem services-Responses chain

Here, the conceptual DPSER framework is used as discussion tool in structuring the findings and their implications in order to tell an integrated scientific story.

3.6.1. Drivers [D] and its push-pull factors

The underlying causal-chain affecting the watershed in general is found to include: population growth and density, agricultural development, the use of wood as primary source of energy, socio-political changes, and the existing land tenure system. Fuel woods supplies 84% of total energy demands of which about 50% is from shrub-lands and wood-lands (exceeding their mean annual increment of woody biomass) and only 5-10% is from woodlots with the remainder from crop residues and dung (MoWR 2008).

Specific to the wetland, there are about 3000 illegal households at the heart of the wetland (Figure 5) with agro-pastoral ways of life. The pull factors that attracts these settlers is related to the 'provisioning' ecosystem services offered by the wetland that comprise: availability of fertile soil suitable for vegetable production, ample water, salty minerals (locally called "Bole") as supplementary food to cattle, grasses suitable for livestock production, high economic return from fattening, dairy farming, horticulture activities, grass sales, and the notion 'communal land with open access to all actors'. Whereas, the push factors that drives these settlers from their original place comprise: climate change, population growth and the corresponding shortage of land for farming and grazing in the surrounding area, intimacy of livestock for the people socio-economic and cultural life, recurrent drought or shortage of grass and water during dry period, absence of communal grazing lands in the highland areas, social value associated with the size of herd, and economic motive to own many cattle.

Figure 5. Partial view of residential houses in the wetland

3.6.2. Pressure [P] on the water quality: unmatched industrial effluents

In addition of the hydrologic stress caused by over abstraction, Belete (2018) reported another anthropogenic pressures on the ecosystem by industries in which the industries surrounding the wetland has been releasing effluents that are quite far from the acceptable limits set by Ethiopian EPA (2003) as evidenced by some of water quality parameters including conductivity, temperature, BOD, COD and sulphate concentrations. Such situation implies that the industries could not conform to the expected standards and the existing wastewater treatment infrastructure used by industries seems no longer sufficient to maintain environmental safety.

3.6.3. Current state [S] of the ecosystem: physical disappearance of the wetland

In terms of physical status, Belete (2018) reported that the size of open water portion of the wetland has been shrinking from the magnitude of 12 km^2 in 1972 into the total disappearance of the open water portion 2007 (Figure 6).

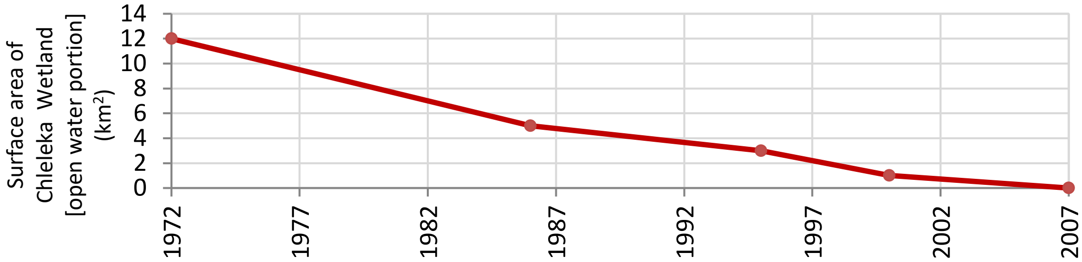
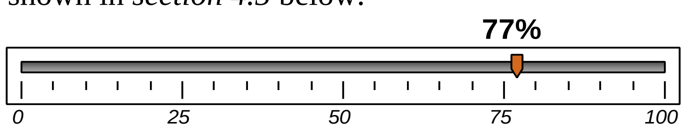


Figure 6. Time series of changes in the surface area of Lake Cheleleka

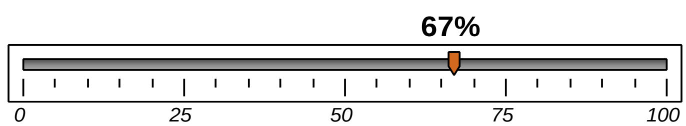
This 12 km^2 loss in 45 years (≈0.27 km^2/yr or ≈2.25% per year) is equivalent to the corresponding disappearance of Haromaya Lake in the Eastern Ethiopia which experienced a complete loss of 8.3 km^2 of the lake surface area in 30 yrs (≈0.28 km^2/yr or ≈3.37% per year) (Alemayehu et al., 2007). These trends tend to confirm the report by Ramsar (2018) that noticed the rate of wetland disappearance to be three time faster than forests.

3.6.4. Summary of potential for the key ecosystem services/ wetland functions [E]

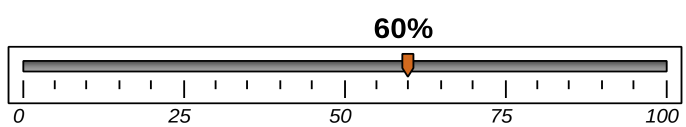
Figure 7 summarizes the potential performance of the four key functions as compiled from previous reports of Belete (2018) and the above results. In attempting to quantify the 'regulating' ecosystem services provided by Cheleleka wetland, it is found to fulfill ≈ 77% performance in water quality improvement; ≈ 67% in ground water recharging; and ≈ 40% in flood peak attenuation. In terms of 'habitat' function, it is also found to ≈ 60% as compared to the ideal biological habitat. While integrating such quantitative expressions into strategic wetland management, they figured out the gaps to be fulfilled and targeted to improve through the appropriate responses as shown in *section 4.5* below.



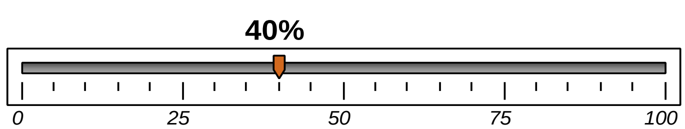
[a] Potential for water quality improvement function



[b] Potential for ground water recharge function



[c] Potential for biological support (habitat function)



[d] Potential for peak flood attenuation function

Figure 7. Summary of relative functional performance of Cheleleka Wetland ('a', 'b' and 'd' are adopted from Belete (2018) while 'c' is own result.

3.6.5. Formulation of management responses [R] / strategies for the wetland management

In light with strategic responses/actions/interventions towards the betterment of wetlands, different terms have been appearing in literature. Ramsar (2010) used the general term 'management' to refer any positive activities on wetlands. Whereas, EPA (1999) and Maltby (2009) perceived wetland conservation and management as two separate concepts while DEC (2012) treats the strategies as management and restoration. Ramachandra (2001) also conceive the concept of management, conservation and restoration differently. NRCS (2008) considered restoration, enhancement, and creation as the three management strategies of wetlands. NRC (1992) reports the similarity of activities such as creation, reallocation and enhancement, to 'restoration' with some difference in the process of renewing native ecosystems to sites where they once existed.

This article systematically defined the possible wetland management intervention and categorized them into four groups of strategic activities (Figure 8) with the intention of providing different options ranging from simple wetland preservation to more complex wetland creation. The formulated strategy is coined and abbreviated as PREE representing *Preservation; Restoration; Enhancement;* and/or *Establishment* strategies. The *Preservation (P)* strategy avoids /minimizes /compensates /removes or prevents the adverse anthropogenic pressures/threats. This term also includes activities commonly associated with the term protection/maintenance; the *Restoration (R)* element repairs/regains the lost functions; the *Enhancement (R)* actions increase /modify /heighten /intensify /improve a specific function within the existing wetland system beyond the original natural conditions that will cause more desirable conditions to prevail. This term includes activities commonly associated with the terms manipulation /directed alteration that involves "making the good even better". Constructed wetland to treat industrial effluents and storm water was also included as part of *Establishment (R).* It is to be noted that the above strategies are not mutually exclusive and not procedural. Rather, they are in the order of general preference and operate in synergy if exist simultaneously. It is considered that any given wetland management responses can be classified in one of the above four general categories.

Having the above strategic management options to guide the community involvement, the site specific management interventions were appraised in a participatory manner. Figure 8 also synthesizes the management approaches and site specific strategies that encompass three strategic management options for wetland Preservation; six for Restoration; two for Enhancement; and two for Establishment are presented.

This PREE strategy tends to argue that wetland management shall first attempt to 'do nothing' and 'artificial/engineering/technological' solutions as the last line of defense. At the same time, it encourages synergism among the different interventions through optimum mix of management activities.

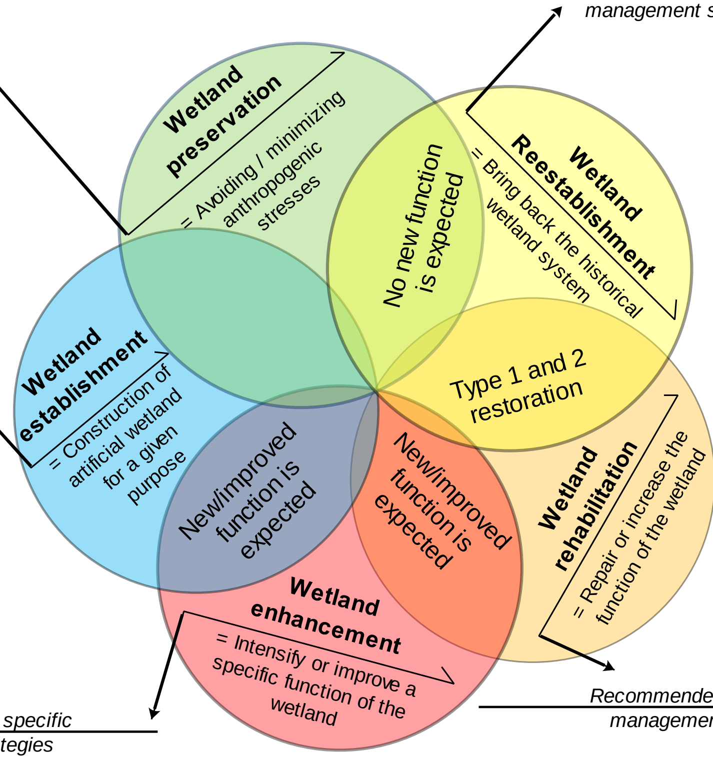
[4] Regulating the total diversion of irrigation water to give chance for wetland recharging and environmental flow
[5] Re-establish the native biota and control exotics and invasive species
[6] Develop mechanisms to control exotics and invasive species

Recommended site specific management strategies

[1] Establishment of social platform for participation, learning, and practice
[2] Devise community based by-laws against wetland degradation
[3] Regulating groundwater abstraction by industries through water tariffing

Recommended site specific management strategies

[12] Constructed wetland for industrial wastewater treatment
[13] Constructed wetland for storm water treatment



Recommended site specific management strategies

Recommended site specific management strategies

[10] Reduction of sediment transport into the wetland
[11] Enhancing groundwater recharge: hydrologic restoration

Recommended site specific management strategies

[7] Plant or otherwise enhance colonization and survival of native species
[8] Increase hydrologic connectivity of the ecosystem
[9] Implement the buffer zone policy

Figure 8. Components of the proposed strategic activities for the wetland management

4. Conclusion and recommendation

This case study captures the applicability of DPSER framework in supporting wetland management decisions and its usefulness as operational tool to guide wetland management. It enables us to integrate the diverse environmental and socio-economic information into an integrated scientific story and holistically handle the diverse issues as a collective whole. It also links scientific findings with "real world" issues.

As synthesized in Figure 9, the strategic management response (R) which is coined as PREE can be applied to the D (drivers) in regulating population pressure on the wetland; in formulating policies to address the issue of climate change and buffer zone management; and in creating awareness among the stakeholders. The management response can also target the pressure (P) in optimizing or limiting the settlements in the wetland; designing proper land use; legally enforcing the industries for proper release of their effluents; application of ecohydrologic solutions to mitigate the water quality deterioration; and in providing environmental flows for proper functioning of the ecosystem. While acting on the environmental state (S) and the ecosystem service (E), the strategic response can target the deficiencies indicated by the field indicators in order to improve performances to the required level. Eventually, it is recommended to optimally mix of the PREE strategies for synergy reason.

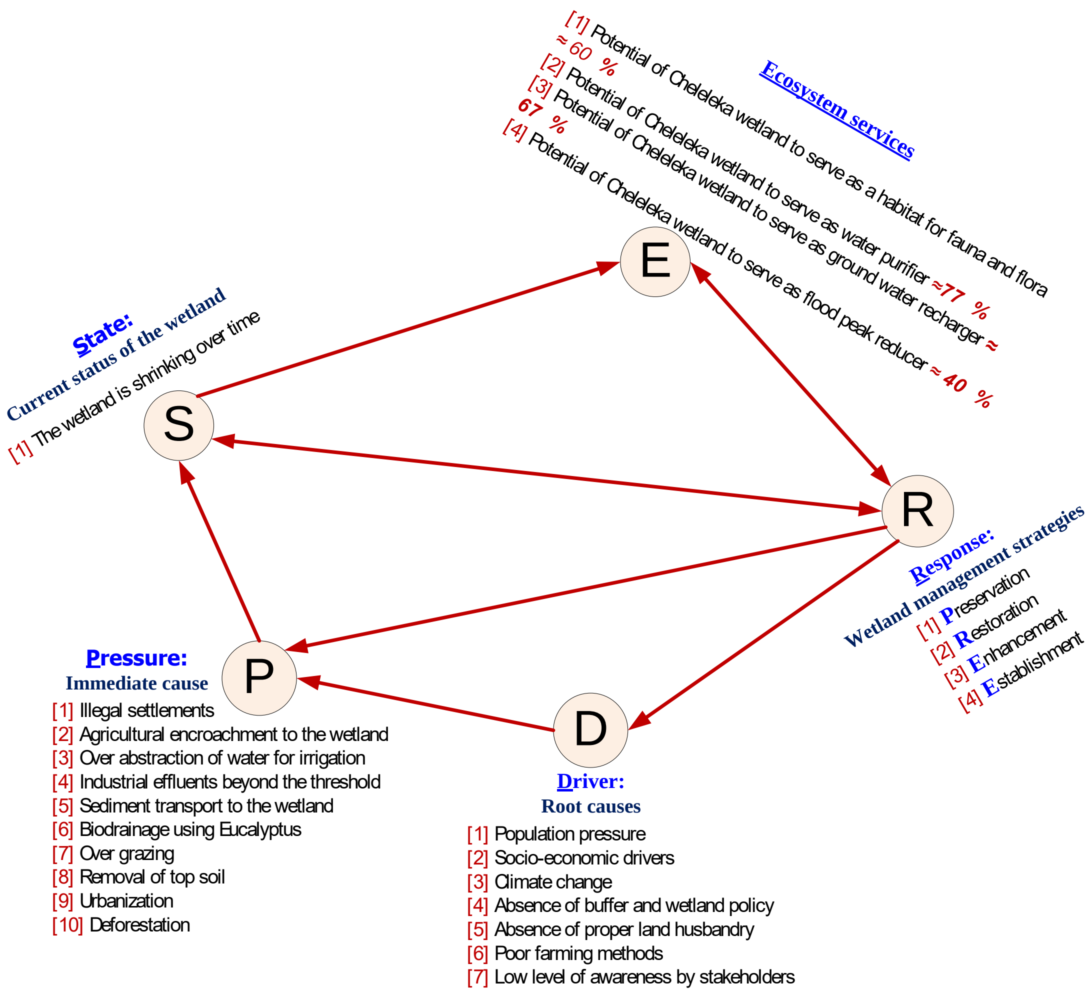


Figure 9. Synthesis of Driver-Pressure-State-Impact-Response analysis for Cheleleka wetland management

Generally, the relationships between the human system and environmental system are complex and may not be well understood (Maxim et al. 2009). The underlying assumption of simple causal relations cannot fully capture the complexity of interdependencies in the real world (Spangenberg et al. 2002). Besides, it is sometimes difficult to provide conclusive evidence of a cause-effect relationship as is required for the application of the DPSIR logic (EEA 2005). A full-fledged causal-link is not always necessary or, if any, it needs long and intensive researches of integrated approach. In this study, the overall causal links were derived from primary data, available information, researcher's and stakeholders' experience on the topic at hand. In this regard, it is strongly recommended to have future researches of similar framework to fill the gaps towards a completed and integrated scientific story to further inform strategic management of the wetland ecosystem.

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