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A SOCIO-ECONOMICAL PERSPECTIVE FOR A HOLISTIC MANAGEMENT OF TEMPORARY WATERSHEDS IN CENTRAL MEXICO BASED ON A SIMPLE MATHEMATICAL MODEL FOR DECISION-MAKERS.

Pedro Joaquín Gutiérrez-Yurrita[1]

[1]*Instituto Politécnico Nacional, Centro Interdisciplinario de Investigaciones y Estudios sobre Medio Ambiente y Desarrollo, México*

ABSTRACT

This paper deals with the development of a new holistic math model to manage watersheds in Central Mexico. Hydrological resources in this medium-dry North-American region supply water to more than 49 million people. In addition, this region is considered as one of the most eco-diverse regions in the world. However, the high population density exerts great pressure on water resources in the area, leading to the edge of extinction to most of its biodiversity. Many mathematical models for estimating environmental flows have been developed, yet no model is truly holistic, even integrated, by not taking into account a variable of extreme importance to the ecological functioning of the watershed, its marked seasonal nature (temporality). Due to this lack of information on how to manage temporary rivers, most managers use conventional indices to estimate environmental flows or at best, use the standard Integrated River Basin Management model developed by http://wwf.panda.org/about_our_earth/about_freshwater/rivers/irbm/ [1] though it is only for rivers with permanent flow. The aim of this paper is to present a reflection on the management of temporary flows, presenting a mathematical model that helps decision makers in their operation programs. The holism of the third culture is taken as the paradigm framework to build the model. It should be noted that an important aspect of the model is its simplicity, since it is to be used by people with little knowledge in mathematics and thus easy to take, and common to all the rivers of the region data.

Keywords: Running waters, Intermittently flowing, Seasonality, Holism, Riverine landscape.

Contribution/ Originality

- Seasonality of watersheds is an important factor as a source of biodiversity.
- Regulated rivers can be modeled as seasonal rivers.
- The proposed model presents diagnostic and control indicators easy to measure.
- This is the first model that really promotes a holistic management for seasonal basins.

1. INTRODUCTION

First of all, we must remember that river basins are dynamic over space and time, and any single management intervention has implications for the system as a whole altering one way or another the landscape ecological balance. Hydrological basin management is decisive for ensuring the continued provision of ecosystem services and for limiting potential hazards especially in areas surrounded by great mountains, deep canyons, erratic weather, environmental seasonality and by far, temporary rivers and streams [2]. The basin management becomes more problematic when facing three major challenges: 1) preserve the great biodiversity; 2) overcome the poverty [3, 4] and by far, 3) fresh water demands on the region is growing as the local population increases [3, 4]. Population never stops growing, and never ceases demanding more resources to exploit until its basic necessities: food, wearing, health, education and recreation are satisfied.

Watersheds of central Mexico are an important factor in the huge regional biodiversity [5]. There are endorheic basins ending in big shallow wetlands or in deep lakes with a lot of endemic biological species [6] but there are also open basins ending in broad estuaries and mangroves that flow into the sea. Waterways across large semi-desert, woodlands, tropical jungle and tropical forest regions, from more than 5000 m high, ending at sea level. Many of these rivers have a strong seasonality and this gives them greater biological richness than that of permanent rivers [7]. Furthermore, streams of central Mexico serve to irrigate grassland of cereals, legumes and corn, mainly; so many people depend on this resource for their productive activities. In addition, if we consider that the population of Central México exceeds 30 million inhabitants and the water for human consumption is a clear priority, so that the dams and channels of rivers are essential to maintaining active life in this region [8]. However, there is a lack of information on how to manage temporary rivers. Most managers use conventional indices of environmental flow management or at best, estimate of integrated management of watersheds with permanent rivers by the use of standard methodologies overlooking that general methodologies have an effect on the results acquired [9].

All the rivers in central Mexico are regulated to a greater or lesser degree [10]. However, not only the river suffers from human control, the entire hydrological basin is altered in its ecological structure (some biological and geological elements were –and are currently-transformed, degraded or eliminated) and thus, their overall environmental performance. Resulting in humanized landscapes left out of their management programs to conserve seasonal rivers [3]. It is worth noticing that another important problem is that local human populations composed in many cases by ethnic communities are the owners of the land and by law, of the natural resources of the land; however, they are living below the poverty threshold [8] so they are using their resources as much as they can. But also, the rivers in better condition of conservation, including their hydrological basin, are located in places with many social problems, and where ethnic people and other communities are in extreme poverty conditions with no options to increase their welfare [3]. So, the way in which they use their natural resources is closer to the philosophy "bread for today, hunger for tomorrow" than that of the sustainability [11]. At present, the efforts for preserving the ecological processes of these important ecosystems, connected in network with other watersheds, are under the paradigm of the "Integrated Water Resources Management (IWRM)" developed by Global Water Partnership from 2000 to 2010 [12]. One of the most important results of this work was the initiative of the seven key elements to a successful "Integrated River Basin Management (IRBM)", established by World Wildlife Foundation since then [12]. However, no reliable and satisfactory results were obtained by this method due to aspects: 1) Social causes: the real and formerly roots that generate poverty were never considered into the model at the same time. 2) Ecological causes: at any time is considered the temporary nature of the streams in the watershed management. Nowadays, the holistic approach may give us some clues and suggestions in how to get benefits from a complex situation, in both, social and natural systems [13].

Consequently, to achieve the famous sustainable development should address the management of biotic resources and water from the threefold perspective of ensuring, firstly, to fulfill the social and economic goals for which it was designed water control in a given basin; including, of course, urban water management [14]. Secondly, to ensure the protection and conservation of ecosystems under such pressure that involves extractive or transformative activities [15]. And thirdly, holistic management assessment has become more inclusive over time, linking future ecological and social changes with current environmental risks and other policy concerns [16]. This three-way consideration is shown in trying to properly manage water resources, as has been the belief that to provide a steady output of water throughout the year, meets the requirement of preserving aquatic environments downstream. This way, an environmental flow to the amount of water that must drain the dams to minimize their impact on streams located downstream [17]. However, most of the time these volumes of water are assigned a uniform value, which is calculated as a percentage of the annual average contribution. From this perspective, environmental flows could be defined as those flows needed to ensure an ecosystem similar to that existing before the construction of dams, even before that human activities were made apparent in the basin towards regional sustainability [18]. From this perspective, studies of environmental flow (minimum flow regimes in channels) should be considered with an academic and practical approach. Thus, management of natural resources (biotic and abiotic) is a reflection of social goals and the scientific understanding of the environment in question, giving us a historical record of both, social and scientific changes [19]. From this perspective, it can be seen that the holistic management of our natural resources has been improved over the trial and error, but to date, has only rarely been possible to anticipate the new challenges posed by society and/or disasters or natural disturbances. The aim of this paper is to present a reflection on the management of temporary flows, presenting a mathematical model that helps decision makers in their operation programs. The holism of the third culture is taken as the paradigm framework to build the model.

2. METHODOLOGY

2.1. Study Area

The Central Mexico region covers an area close to 150,000 km^2 with an estimated population of about 49,123,993 people; almost all people are living in very big cities with more than 1,000,000 people each, but the other people are dispersed in thousands of small ethnic communities scattered across the sierras, especially in natural protected areas, like Biosphere Reserve of Sierra Gorda [8]. In the agricultural fields as well as in the Sierras there are high rates of migration recorded for the reason that the field is considered increasingly less profitable. Agricultural fields and deciduous forest in middle and lowlands dominate landscapes of the area. Oak and pine forests are confined at the top of the Sierra, covering part of the Trans-Mexican volcanic belt and part of the Eastern and Western Sierra Madre [20]. General statistical data of watersheds of central Mexico considered in this regional study are shown in Table 1.

The center of Mexico is composed essentially of three great watersheds: *i*) Lerma river basin, *ii*) Pánuco river Basin, and *iii*) the Valley of Mexico Basin also known as basin of Anáhuac (Figure 1).

- The Lerma River is a 708 km-long river in central Mexico that begins in the Trans-Mexican volcanic Belt at an altitude over 3,000masl, and ends where it empties into Lake Chapala (1500masl), Mexico's largest shallow water lake of freshwater [21]. The river has a flow towards western México. The basin is endorheic allochthonous. At least three climates are distinguished in the region, however, the rainfall is similar between them: from June to September. Dry periods are intensified in the spring [22]. Lerma-Chapala basin is notorious for its pollution, but the water quality has demonstrated considerable improvement in recent years due mostly through massive upgrading projects of sanitation works.
- The Pánuco River is a 510 km-long river in central Mexico that begins in Moctezuma river system close to the Anáhuac Basin at an altitude over 2000masl, and ends where it empties into The Gulf of México (0masl), but only the last 15 km are navigable for larger ships [21]. The river has a flow towards northeastern Mexico. The basin is exoreic allochthonous. The greatest rainfall is from June to September. Dry periods are intensified in the spring [22]. This basin is probably the most polluted basin in Mexico.
- The Anáhuac basin is a closed basin that is geologically divided into three hydrologic zones: the low plain, which is essentially the bed of now practically extinct five former lakes, the piedmont area, and the surrounding mountains [6]. The old lakebeds correspond to the lowest elevations of the valley in the south and are mostly clay with high water content and are almost entirely covered by urban development. In the piedmont area these clays become mixed with silts and sands, and in some areas close to the mountains, the piedmont is largely composed of basalts from old lava flows. The valley is enclosed completely by mountain ranges, from which flow rain and melting snow into the valley's hydraulic system. This groundwater flow produces a number of springs in the foothills and upwelling's in the valley floor.

It is important to mention that every year, two estimations are carried out of droughts in North America as part of the "North American Drought Monitor" (NADM) project. For the first estimation, corresponding to the end of the dry season, in May 2008 the drought conditions in Central Mexico prevailed abnormally dry conditions (D0) to drought extreme (D3). But more importantly it is to say that in the second measurement, taken at the end of the rain season (October) extreme drought increased considerable in the entire region.

This region is in the junction of the Nearctic and Neotropical Biogeographical regions, including four physiographical provinces: Neovolcanic axis, the Central Plateau (Bajío), Sierra Madre Oriental and Sierra Madre Occidental. Because of the high variation in altitude (0 to +5000masl) and the three climates identified (warm, dry, temperate), the following types of vegetation are found in this area: desert scrub, thorn woodlands, pine forest, oak forest, temperate hardwood forest, low tropical deciduous forest and agricultural lands. Many aquatic fauna and macrophytes naturally inhabit shallow, clear, running waters, riffles areas of the streams with no pollution or not greatly altered by man. Riparian vegetation, rocks, pebbles and cobbles are of considerable importance for invertebrate survival, because during the night, they rest and look for food within macrophyte mass and roots, and inside the great amount of debris deposited in river or stream pools. During the day, aquatic insects hide under the rocks [7, 23-25].

Seasonal aquatic systems (temporary rivers and springs) are the most exploited resources for touristic and productive activities, however, although there is much work in limnology, there is an important information gap concerning their ecological functioning [10]. Practically all-aquatic systems are subject to wide variations in flow due to seasonal weather in the region. Physicochemical of many water bodies ranged from 20 to 28°C; 8 to 12 mg l^{-1} of oxygen; pH from 7 to 8, total hardness ranges from 90-350 mg $CaCO_3$ l^{-1} [23]. Vegetation that surrounds the rivers are mainly gallery woods (*Taxodium mucronatum*), pines and oaks in the springs, and banana, mango and peach trees in plantations (canyon's low lands); though hydrophytes are scarce in several places, *Aster subulatus*, *Cyperus flavescens*, *Cyperus niger*, *Typha latifolia* are the most representatives of the highland streams. The exotic macrophytes such as *Eichornia crassipes*, *Egeria densa* and *Lemna gibba* are the most abundant in slow-flow rivers; *Lemna aequinoctialis*, *Polygonum lapathifolium*, *Bacopa procumbens*, *Bacopa monnieri*, *Hydrocotyle verticulata*, *Eleocharis macrostachya*, *Najas guadalupensis* and *Potamogeton diversifolius* are other macrophytes present in many aquatic systems of the SGBR [7, 20]. Major animal community is comprised by benthonic macroinvertebrates (*Macrobrachium carcinus*, *Macrobrachium olfersi*, *Laccophilus* spp., *Tropistermus* spp., Tricoptera, Heteroptera, Notonecta, Diptera –Culicidae and Chironomidae- [24] and larvae of Odonata (*Hetaerina* spp., *Anax* spp., *Aeshna* spp., *Libellula* spp.) [26] zooplankton community is assembled by Daphnia, Copepoda and Amphipoda; the most representative fish species are *Poecilia mexicana*, *Heterandria bimaculata*, *Goodea atripinis* and *Astyanax mexicanus* [7]. The ecological importance of this region can be seen in the large number of new species discovered to science of aquatic macroinvertebrates in recent years. Terrestrial habitats, mammals and birds are much more studied and a very good synthesis can be found in [27].

2.2. Epistemological Background

Estimation of environmental flows is a hot topic resorted by hydraulic engineers, ecologists, planners and politicians, but far from being resolved, is practically in the early stages of its development. The lack of good predictive models is because they are constantly modifying management paradigms of nature, the way in which policy is made and how the ecosystem functioning is conceived. And now the human rights component, specifically speaking of the right to an environment adequate for its development, access to information, the right to take part in decision-making and access to justice is integrated. Thus, the paradigm of integrated watershed management, widely used in the early 90's, is now almost obsolete to make way for holistic paradigm. This study is not intended as an exhaustive list of all the methods used to calculate environmental flows or minimum flows that would be the subject of a review article. Only the most used models currently worldwide will be mentioned. However, it is important to note that any old or new model are taking into account seasonality, hydroperiod and water regime of rivers [18, 28-39] and that some newest approaches are considering of great importance the economical factors to make any political decision, so those models contemplate the Discounted Cash Flow Analysis to value a management project when urban and/or agriculture water systems are involved [14]. Therefore, the model proposed in this work is entirely new.

The Official Mexican Standard [40] published in 2002 deals with Conservation of Water Resources but only states that there are some specifications to determine the ecological flows of national rivers. Unfortunately, because no methods were established, in its second transitory article states that the minimum flows are known by an unofficial standard or by studies done by individuals. Thus, it is unclear which method should be used or what variables to take into account when setting minimum flows in a given river. Thus the Mexican standard that establishes the methodology for calculating the minimum river flow is elaborated (at the publication of this article this rule is not official yet) in 2012, called [39]. This rule proposes three ways of measuring environmental flows, one called hydrobiological which is what counts in a way aquatic wildlife in hydraulic systems to manage [33]. A second way is the conventional method to set the minimum and maximum flows, emerge from the methodology of Tennant [30]. And while the third form contemplates that there may be a holistic method draws on the work of King, et al. [35] which is good, but complex to follow and therefore impractical for quick decision-making with a degree of precision.

2.3. The Holistic Approach

A modern way of addressing problems in the management of natural resources is the holistic approach to the study of natural systems. This approach integrates all relevant information on the socio-economic users of the resources of a watershed, with information gathered from the ecological processes of the ecosystems involved in the operation of the landscape [41]. It is worth noting two things respect to this approach that make it different from other similar approaches (consilience, integrative basin management or ecosystemic planning): *i)* to take special attention on the phenology of rainfall and the monthly mean humidity of the area, and *ii)* to use the knowledge of all the sciences that relate to nature and man, including politics and economics specific to the study area, but does not do a synthesis of this knowledge [41-44]. In other words, it integrates without scientific reductionism knowledge of different sciences. This paradigm of gathering knowledge is able to analyze complex systems, such as planning in landscapes networking, under different perspectives in a systematic way simultaneously [45]. It is understood, then, that a hydrological basin is a complex system considered like the basic unit of operation, where the interactions between water, earth, air and human activities –technology included- are very tight and dependent on each other [44].

3. RESULTS

The mathematical model generated meets three conditions simultaneously: *i)* must have high degree of accuracy; *ii)* variables must be easily measured; and *iii)* efficiency indicators must be easily to monitor continually and cost effectively. High degree of accuracy means that the variables taken into account serve as indicators of system diagnosis, effectiveness of control measures and management, and to predict future scenarios following the same trend of uses and intensity of uses.

For holistic studies to provide a basis for decision-making, it is necessary to overcome three major challenges in the same political decision: State development policy, social, and environmental issues.

1. *State development policy*: Public administration has a direct interference in development by its territorial planning strategies, and the concept of environmental justice, which is different from social justice, although they are closely related. Eco-justice is distributive in character and that should not bear the entire burden of environmental conservation the inhabitant of the areas preserved or peasants with limited resources [46].
2. *Social issues*: Large bodies of epicontinental water built in Mexico (big dams) and the regulation of riverbeds of Central Mexico are used for various purposes, the most important are: drink water supply; irrigation; industrial; power generation; public services; and finally, preservation of environmental flows (Article 41 of the National Water Act, amended on 29/04/2004).
3. *Environmental issues*: Conservation of the ecological processes of ecosystems from the hydrological basins under the pressure that involve the extractive or transformative activities. Both issues overlapping like complex systems. They are not aggregated into a system unit (integration) but rather which are systems with emergent properties at each hierarchical level of organization [47].

Under the holistic paradigm, the study of watersheds is built from two perspectives and two subjects. Perspectives because we have in essence two ways to see the world, the *ecocentric* and the *anthropocentric*: Ecocentric perspective is an idealized perspective of the nature functioning, because it must be analyzed in detail the structure and functioning of all ecosystems involved, particularly the seasonal river (analyze each section of the river separately and together, and reservoirs), with all the existing anthropogenic modifications (natural and anthropogenic phenology). From this information, calculate the ecological flow that would ensure the integrity of ecological processes in the watershed. Anthropocentric perspective is the realistic one, because in no case should be questioned the priority uses of water resources, while respecting the principle of environmental services to be implemented to manage aquatic environments and overall basin. Analyses should be made monthly because many aquatic systems show a marked seasonality in water regimes.

3.1. Under the Ecocentric Perspective Must be taken into Consideration, At Least the Following Factors (E):

1. Morphology and topography of the basin in general and the particular channel;
2. Monthly and daily weather (temperature and rainfall), taking into consideration relative humidity and sun hours every season.
3. Physicochemical characteristics of water and geology of the basin;
4. Average monthly flow rates or contributions of each river basin as well as the hydroperiods and water regime of each type of riverbed habitats (places with or without vegetation, vegetation types and substrates, rocks, pools, etc.);
5. Ecological characteristics of networked ecosystems: biological diversity, density, distribution, dispersal patterns, and organization among biological populations (ecosystemic complexity).

By way of example, Figure 2 shows how there is a slight change in the number of biological orders in a permanent water body (Boyecito), and how a seasonal river varies greatly in abundance of aquatic orders before its regulation by building a dam, and how this abundance remains constant in section regulated as the river acts as a permanent one, losing seasonality and the natural flow [24]. Fig. 2 also shows how there is a progression in the ecological assemblages of the present biological communities [26]. The seasonality of the system is a determining factor for a biological association becomes dominant in a given period [7]. If this fluctuation is broken, changing the water flow of the river, the assembly can be lost at that time when it contained few individuals. And if that association had rare (less than 1% of all species in terms of relative abundance of individuals of the population), this species may become extinct or at least be endangered [23] this is the case, for instance, of the endemic crayfish *Procambarus yagoii* (description of this new species for science is in progress).

3.2. Under the Anthropocentric Perspective, We Take into Account Factual Indicators of Socioeconomic Status of Users of the Networked Basins *(A)*

1. Benefits that would have for the management of water in the short, medium and long term;
2. Present and potential welfares to keep the water system and the natural or historical flow;
3. Consider a time series analysis of the uses of basin water resources, in intensity and weekly amount;
4. Estimate the efficiency and effectiveness in the present form of using water resources of the region;

5. The invasion of introduced species in rivers is facilitated by the alteration of flow regimes, so we need to estimate ecological impact of exotics in the basin in order to stop or to reduce inter-watershed transfers.

The issue of invasive species is of particular importance in the anthropocentric perspective. Man has always loved to travel with their pets, favorite foods and recollections of their origin. Human migrations have been responsible for expanding the distribution of many species of plants and animals outside their normal distribution range. Currently the most successful introductions are being made deliberately, preparing natural systems so they can welcome the invaders. Clearly, the species to be introduced must have certain characteristics to adapt quickly to their new habitat. If these two conditions are not met then it is a failed introduction. One of the most representative examples of environmental damage that can produce an introduced species, is the crayfish *Procambarus clarkii*, shipped with aquaculture purposes from Louisiana to southern Spain in 1972 [48]. Figure 3 shows the ecological alterations that this species has produced in temporary freshwater marsh of Doñana National Park (Spain). *P. clarkii* has been demonstrated to be an engineer species of the ecosystem, physically transforming its environment and altering the availability of resources for other species. These changes have been achieved principally by structural modification of the freshwater systems [49]. The crayfish bring this about by reducing or totally eliminating the aquatic macrophyte beds [50]. The most important ecological consequence of the reduced aquatic vegetation cover is the enriching of the water column with nutrients, which favor the development of phytoplankton communities, changing the ecological balance from fresh to turbid water [51].

3.3. Hydrological Subject (H)

1. Water regime: the way in which the system filled with water up to the maximum annual average;
2. Hydro period: the rate at which water fills the system, the retention time and the time of loss of water until the system returns to the minimum flow;
3. Extreme water flows (both minimum and maximum): Extreme minimum water flow can occur in drought. Extreme maximum water can occur during periods of extreme rainfall. These extreme events include catastrophic rains (storms, flooding's) or severe drought;
4. Estimating temporal pulse of total water recharge system: Estimating temporal pulse total water recharge system. The duration of the events (rain or drought) are determining factors in understanding ecological processes of seasonal rivers, their watersheds cross (influence of the riverbanks) and longitudinal (along the riverbed). These events in the seasonal rivers are responsible for the biological richness of the system.
5. Influence of artificial water bodies: dams, reservoirs, ponds, water retention and channeling of rivers, ostensibly alter the natural hydrology of the rivers, especially the hydroperiods of seasonal rivers, because most of the time the human management of these water bodies propitious than ever to dry out the system.

Managing a system that is repeatedly affected by extreme events is not easy, but not impossible. Figure 4 shows how change species richness of a keystone group in the functioning of the ecosystem. This guild could be used to predict how extreme variations in river flow affect the ecological processes that maintain it's functioning.

3.4. Integrative Subject to Develop a Simple Math Model *(SE)*

Due to the model for decision making should be operated by technicians or users with little or no schooling, this should be as simple as possible to deliver them in a excel sheet, where users just have to input data (data must also be fast tracking from themselves) and get results via computer or calculator. It will have a holistic flow each month. The methodology is divided into five steps:

1) We have to divide the river into reaches. A reach of the river is the area of the river that has different characteristics clearly marked with the adjacent top and bottom. The river is considered as a continuum gradient of ecological conditions (physical, biochemical, biological and entropy gain, for instance), where the water goes down is a consequence of what has occurred upstream, thus the biological organization in the rivers conforms structurally and functionally to kinetic energy dissipation patterns of the entire system [52]. Rivers could be divided into three reaches:

Headwater: Production system is less than ecosystemic metabolic processes ($P < R$)

Medium-sized-stream: Production and ecosystemic metabolic processes of the system are equal ($P = R$)

Large-rivers: Production is greater than the ecosystemic metabolic processes ($P > R$)

Where P is the total production of the reach and R is the total ecosystemic metabolic processes of the reach. The head is dominated by autogenic biomass while mouth is dominated by allochthonous biomass.

2) We must consider that the river may have regulated sections and unregulated sections, but stability of the river ecosystem may be viewed as a tendency for reduced fluctuations in energy flow, while community structure and function are maintained in the face of environmental variations including small or huge human impacts, such as big dam. The unregulated sections should be used as units of measurement of mean monthly flows estimated contributions from natural runoff, with a value of probability of occurrence of a given event. In the sections regulated is taken into account the amount of water used for each of anthropocentric activities that poured through the gates of the reservoirs. These flows should be estimated in each part of the river located between two controlled reservoirs.

3) The third step is an ecological and socioeconomic assessment of the basin under management. The ecological assessment emerges from the scientific characterization of the ecological structure and functioning (natural resources and environmental services). Among all the factors are especially important to consider the hydroperiod and biological communities (macroinvertebrates, fishes and macrtophytes). The first is because it will indicate the amount of water and the speed of the current should carry the channel at each weather season. The second is

since the community structure and composition of these populations remain more stable over time, especially with constant flow seasonally.

4) Within the economic and social assessment must take into account the current and potential uses of all resources of the basin, and the services to be offered in case the system is keeping unchanged its natural (unregulated). By establishing a natural resources asset class, is in a position to be accounted for as assets inexpensive produced products, for which, it must be assigned monetary values (prices, production costs, costs of depletion and degradation, etc.), in order to integrate the other cash flows of the economy and to calculate the domestic raw product.

The following equation represents a simple linear model (do not take into account the weighting factors because it is a model to help people, not experts in mathematics, to make social and environmental decisions; complicate the model only makes it more understandable to the non-expert people who must to apply it:

$$SE_{t+1} = SE_t + (I_t - D_{SEept}) - (AG_{SEenpt} + AG_{SEanpt} + DG_{SEanpt}) + (DI_{SEenpt} + DI_{SEanpt}) + (R_{SEept} + R_{SEenpt} + R_{SEanpt}) \quad \textit{(eq. 1)}$$

Where: SE_t+1=total assets at the end of the period; I_t=total non-produced environmental assets; SE_t=total assets at the beginning of the period; AG_{SEenpt}=depletion of non-produced economic assets; AG_{SEnapt}=depletion of non-produced environmental assets; DG_{SEanpt}=degradation of assets environmental non-produced; ΔI_{SEenpt}=change in non-produced economic assets; ΔI_{SEanpt}=change in non-produced environmental assets; R_{SEept}=re-produced economic assets; R_{SEenpt}=revaluation of non-produced economic assets; R_{SEanpt}=re-evaluation of environmental assets not produced.

5) What is needed at this moment is to assign monetary value (price) to each non-produced assets (natural resources) involved in the above equation, for which there are basically three methods: the net income method (NIM), the user cost method (UCM) and the discounted cash flow analysis (DCFA) [14, 53]. The NIM value units are based on the difference between income, with the current market value of the estimated inflation rate by the Bank of México (or any central bank that could be used as a national or international reference), and total costs of resource use. The UCM assesses the application based on the cost of exhaustion, which is estimated as a part of the present value of expected net income over the lifetime of the resource. The DCFA is a method of valuing any asset using the concepts of the time value of money in order to get the net present value of the asset, which is taken as the value or price of the cash flows in question.

The analysis of the perspectives (ecocentric and anthropocentric) and the subject of hydrological, results in a value on a scale from zero to ten in each. All of the five features that are assessed in each perspective and subject have three options of values: 0, 1 and 2. Zero indicates that the system or variable is totally damaged, misused or abused to the maximum, while the value of two indicates exactly the opposite, the variable is in good condition, preserved and in their natural state. The sum of each value is the final value of the perspective or subject analyzed.

These final values are added up to give a global environmental value (GEV) that represents the ecological status of ecosystems under exploitation:

$$GEV_{t+1}=(E_1+E_2+E_3+E_4+E_5) + (A_1+A_2+A_3+A_4+A_5) + (H_1+H_2+H_3+H_4+H_5) \qquad \textit{(eq. 2)}$$

Finally, the two subsystems are integrated to have the bottom line of the monthly management. The decision must come from comparing bottom lines of at least three integrations. The first taking into account that in managing a flow with minimum monthly flows, other ecological and economic elements are modified, usually decreases or eliminating altogether, as the final production of natural resources and produced changes. Estimating the maximum flow rates achieved for that month, which would bring the economic system to have the same or more products obtain another balance, i.e. more water use does not necessarily lead to more production in a given season. The third balance is obtained by considering environmental conditions closer to the natural average month. Monthly final balance (MFB):

$$MFB_1=SE_1+GEV_1; \quad MFB_2=SE_2+GEV_2; \quad MFB_3=SE_3+GEV_3 \qquad \textit{(eq. 3)}$$

An illustrative example of how holistic manage can be used to discern what may be the best choice to manage natural resources in a way that is most appropriate for regional development and conservation of the ecological functioning of seasonal rivers is shown in Fig 5. This figure shows the production of benefits to both consumptive use (i.e.: water for irrigation) and non-consumptive use (i.e.: contemplation) and quasi-option values (bequest value, existence value, support and value option value) that ultimately are willing to pay. Finally, in response to all types of benefits and costs of the option is not taken as a result of a decision, an assessment of recovery of the affected ecosystems, whether real or potential should be made. Figure 5 shows a proposal of major events that may occur to determine the size classes' structure of *P. clarkii* populations in Doñana National Park freshwater marsh (Gutiérrez-Yurrita in prep.). This crayfish was deliberately introduced into freshwater marsh ecosystems in southern Spain almost 40 years ago and has totally changed the shallow water balance of many aquatic systems in the Park [44]. The Holistic perception to manage Doñana National Park must include, in an integrated policy, the emergent characteristics of this complex systems, not only the three great themes (economic, social and environmental), but perspectives of how to get benefits from an undesirable situation. Only in this way we can assure conservation policies in an area very crowded by tourists, fishermen, peasants and pilgrims to the biggest religious fest in Spain, the Rocío.

The two basic subjects for estimating environmental flows are more technical than theoretical, as were the perspectives presented: *Hydrological* and *integrative*. We have chosen these issues to combine different aspects of the physiography, ecology and natural resources of the watershed and man's relationship with it.

4. DISCUSSION

All approaches for estimating environmental flows may have strengths and weaknesses, but the truth is that for management to resolve the conflict between conserving a natural resource and develop a village should be viewed in a holistic perspective. Holistic approach to manage any natural or man-managed landscape is a new way to understanding that watershed is a multifunctional territory where the binomial forces "man-nature" do have to interact at different temporal-space scales, that means, we do have basins networked [6, 44]. The holistic paradigm often includes the view that systems somehow work as a whole and that their functioning cannot be fully understood solely in terms of their constituent parts [13, 15]. Territorial planning strategies allow us to determine other policies in order to get a holistic management of the central Mexican basins. Policies generated by this paradigm concerning social aspects (farmers who traditionally use the water to irrigate fields with crops unsuitable for the region, fishermen and other locals that use to poach to survive or to improve their profits, peasants who "steal their own water" and used without current technological advances and unprofitable crops, but with high cultural level, for instance); environmental services (conservation of natural areas can help us improve the already degraded environmental services and stop the deterioration of the ecosystem functions of landscape); and economic and technological issues (an integrative watershed program may enable us to diversify production options in the context of conservation biology) could be the reflection of a well-planned management strategy to the park [47].

Any type of watershed management models, developed previously to the one I propose in this paper, to a greater or lesser degree are based on anthropocentric, utilitarian and immediateness criteria. In some programs the holistic planning is confused with the consilience and the integrated river basin management, but do not really handle this perspective. The long-term studies and those contemplating seasonality, water regime, relative humidity and hydroperiod are absent. If man has regulated all rivers, such as in the Centre of Mexico, it is impossible to have an environmental flow management without considering these factors, as well as the changing needs of the population [54]. Management must therefore be dynamic [4].

Mexican standard setting the minimum flows in Mexico is unique [39] no international counterpart do exist. However, the holistic aspect that handles the model is very complicated to be used as a mathematical model on a daily basis, it has no way to quickly assess how the management goes, and the effectiveness of the measures taken. It is also very difficult to measure. The model I have developed presents diagnostic and control indicators easy to measure, which immediately tell us how the system behaves and the mathematical procedure used, a linear regression by separate and specific steps, which makes it easily applicable.

In Mexico, the regulation states that private persons may build their own studies to establish environmental flows; however, so far, studies have been ending to establish the country's watersheds very generally, have not yet been able to establish ecological flows anywhere. Possibly, as explained before, due to the complicated methodology proposed in the Mexican Standard [39] and, maybe because of the lack of data to feed the model. In short, what we have in Mexico is not a model of environmental flows, but a functional characterization, eco-geographic basins of the country. From this point of view and following the functional criteria basins of central Mexico are classified into high and media altitude basin [55]. And from the eco-geographic classification, the vast majority of the basins of central Mexico belong to exoreic allochthonous distant type; only the Anáhuac basin is endorheic autochthonous by its height and high slope degree [56]. The first classification although can be used for its simplicity, is so simple that it does not really give accurate information for making decisions about the distribution of water for various human activities and the amount of water that must be maintained to ensure the capacity of resilience of the affected ecosystems and its landscape ecological functionality. Meanwhile, the eco-geographical classification is useful since it helps to understand that the management of the rivers of central Mexico should be done in a hierarchical manner, following spatial and temporal scales, as outlined in the ecosystemic management paradigm [11]. The eco-geographical approach and the bio-hydrological method recognize the heterogeneity of allochthonous landscapes in the watershed, especially in very large basins. Nevertheless as González Del Tángano and García De Jalón [38] pointed out, these attributes define the morphology of basin, reflecting solely a static view of the watershed. River ecosystems are highly dynamic; differences in flow depend among other factors on weather spirals and human uses must be accounted for in the model, for its part, also recognized the importance of an endorheic basin in terms of homogeneity of the landscape and scale of action on it, in the sense that the work on a smaller scale, cartographically speaking, is more sensitive and therefore vulnerable to human activities and environmental impacts. However, for the model to be functional in central Mexico must have a simple way of viewing extreme weather events such as drought in the region, especially at the end of the rainy season, repeatedly. A drought is becoming more pronounced by the possible climate change experienced in the region [47].

The classifications of the basins of central Mexico, according to their level of priority for the conservation of biodiversity, are classified utmost priority and high priority [57]. These same categories are presented in terms of a classification by human impacts, being extreme in the Anáhuac and Lerma basins and high in Pánuco Basin [58].

To sum up, the study of the ecology of keystone and invasive species is of great importance in understanding future events in the population dynamics of all ecological association in every ecosystem. These studies are also of the greatest importance in determining the final structure of the landscape and global ecological functioning of the networked basins that must necessarily include migratory and reproductive behavior of species, etc., which to a certain extent determine the management strategy to be implemented. When there is an excessive increase in the density of certain species in a community and conditions are stressful, the growth of some species will be deficient; they will develop less and reach maturity without having attained the energy reserves and necessary size to leave offspring in optimal conditions. Something similar occurs when a resource is overexploited. The strategy of survival of the affected species is reproduced to a size smaller than normal, which leads to use their habitat more intensively. The synergistic result is a disturbance of the ecological structure and a shift in the functioning of the system to be more intense in some ecological processes. In all these changes the importance of doing studies at different scales of time and space, as noted previously, is appreciated.

5. CONCLUSIONS

- The seasonal river management issues should have geophysical, biological, ecological, social, and above all, economic aspects.

- A region with severe problems in living standards is not able to protect their ecosystems without first satisfying their basic needs and some pleasures.
- Seasonality of the rivers of central Mexico is one of the variables that promotes high biodiversity of the region.
- Communities of indigenous people, besides losing what little they have, will move to the cities or immigrate to the United States. The field was abandoned and the ecological integrity of ecosystems resilient will be lost before the next decade. These situations are because no systematic management of water resources with a holistic approach is applied by authorities, which is the result of a lack in models to estimate efficiently environmental flows.
- A holistic approach to the management of watersheds would be favorable since it allows the evaluation of a comprehensive policy management, which would include a more ample focus considering the social, economic and administrative sectors of complete landscape.
- The model I have developed presents diagnostic and control indicators easy to measure, which immediately tell us how the system behaves, and the mathematical procedure used, a linear regression by separate and specific steps, which makes its application easy. This model is new and unique at the moment.

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Table-1. General statistical of watersheds of central Mexico considered in this regional study.

Hydrological basin	[1]Adminis-trative Region	[2]Mainland surface area (km^2)	[2]Renewable water resources (hm^3)	[3]Population up to December 2008	[4]Annual rainfall (mm)	Basin type
Lerma	VIII	47,116	4,742	22,326,511	816	Endorheic allochthonous
Pánuco	IX	84,956	20,330	4,982,167	914	Exoreic allochthonous
Anáhuac*	XIII	18,110	3,515	21,815,315	606	Endorheic autochthonous

* Anáhuac Basin is considered by National Water Commission like Waters of the Valley of Mexico[1] [8, 59, 60].

[1] In this work I prefer to call the basin by its original name for two reasons, the first is obvious, its original name is Anáhuac and has a prehispanic meaning that marked the ideology of people. And second, calling it Valley of Mexico has brought confusion on how to manage their water resources, and this confusion has made the basin is managed as a valley, or at most, as a exorreica basin, regardless of whether it really is a geologically young volcanic closed basin, home to a large lake divided into different sections by salinity. For more information see [44] P. J. Gutiérrez-Yurrita (2009)..

Figure-1. Area of study. Principal basins of the Central Mexico. Black lines mark the boundaries among watersheds, while the gray lines represent the major rivers in each basin. The circles represent sites where the largest cities in the region are located: 1) México City; 2) Querétaro; 3) Tampico.

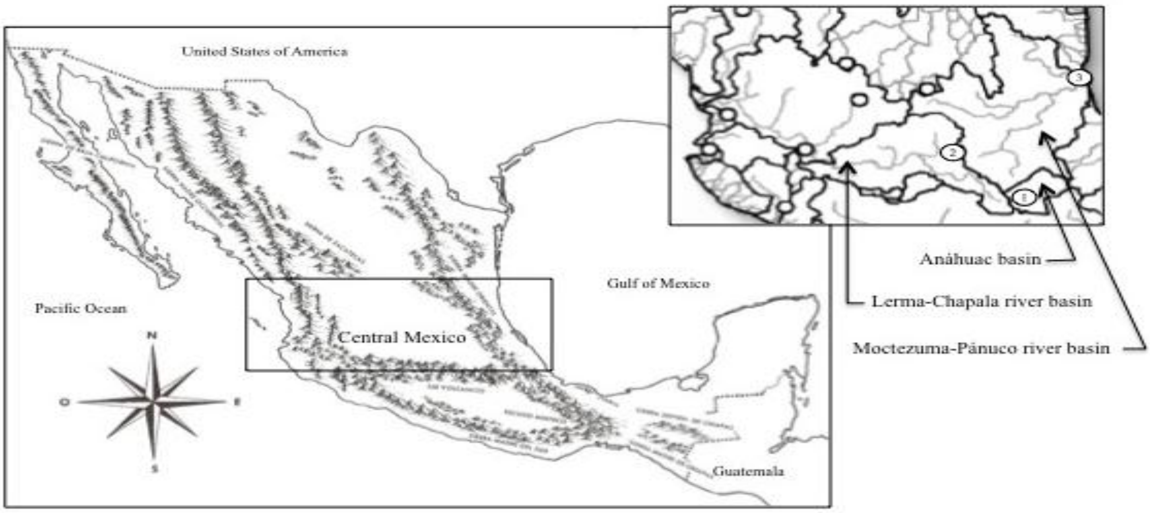

Figure-2. Taxonomic seasonal distribution of aquatic animals respect to the hydrological regime in regulated and unregulated aquatic systems. Boyecito is permanent water systems while Tecozautla is a highly seasonal aquatic system. Hypothetical general curves show how both the dominant and rare species are two fundamental components of a system. The interpretation is based on a collection of 18,809 individuals belonging to 22 orders of macroinvertebrates in aquatic systems of Reserva Biosfera Sierra Gorda. The dominant orders were only 4: Diptera (25.9%), Hemiptera (18.9%); Ephemeroptera (16.3%) and Odonata (10%). Data were taken from Hurtado, et al. [24].

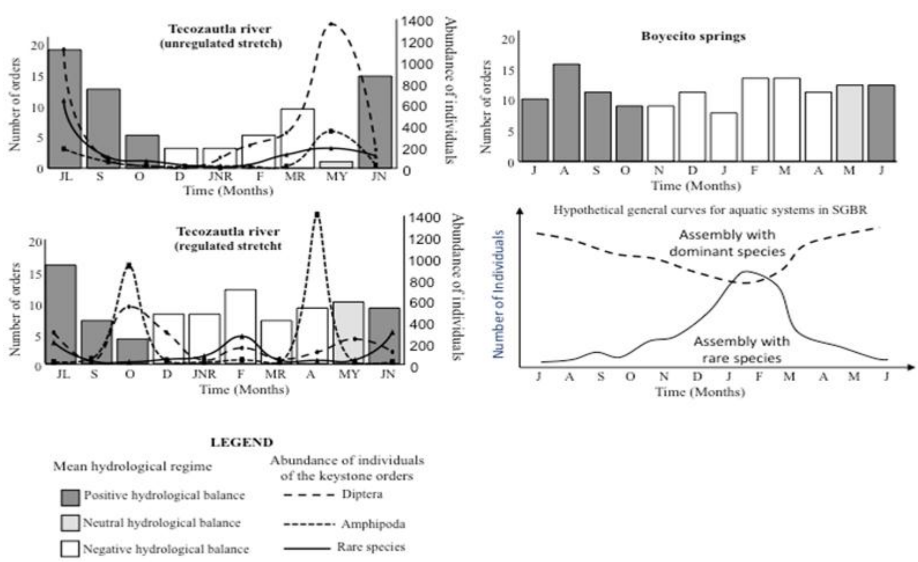

Figure-3. Overall functioning of a shallow water system, when it is invaded by a key and engineer species controlling the ecological functioning. Before the invasion of crayfish, the ecological balance of the system was clear water. Crayfish affected the biomass of aquatic macrophytes allowing greater light penetration and wind action, suspending nutrients in the water and favoring the growth of phytoplankton and algae. The result is a balance of turbid water.

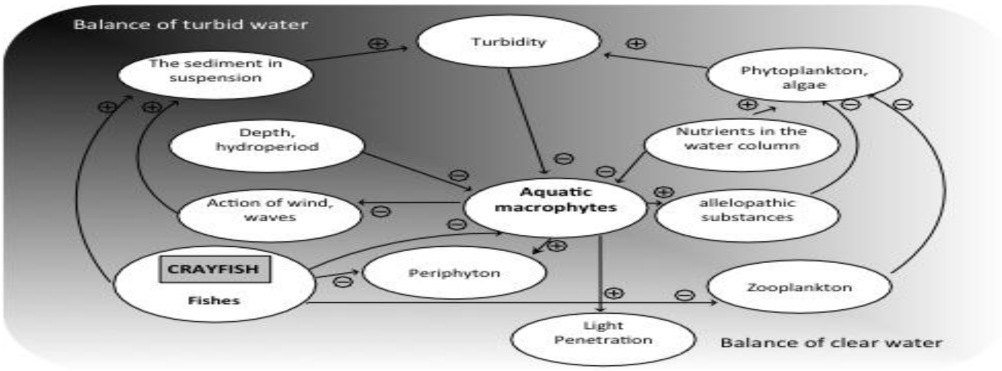

Figure-4. General model of the main factors that influence Odonata diversity in Moctezuma River System. The model considers the synergistic effects of the integration of human impacts with recurrent natural phenomenon. Data were taken from the work of Alonso, et al. [26].

Figure-5. Proposal of major events that may occur to determine the size classes structure of *P. clarkii* populations in Doñana National Park freshwater marsh. (Data from Gutiérrez-Yurrita et al. in prep.).