SUSTAINABLE MANAGEMENT OF LAKES IN CONNECTION WITH MITIGATION OF ADVERSE EFFECTS OF CLIMATE CHANGE, AGRICULTURE AND DEVELOPMENT OF GREEN MICRO REGIONS BASED ON RENEWABLE ENERGY PRODUCTION

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Abstract

Lake management is extremely complex and requires a coordinated effort of research institutions, community groups, individuals, landowners, and government. Lakes constitute an important group of natural resources due to their ecosystem services and often unique cultural environments. Climate change is a growing concern, which particularly strongly affects shallow lakes. The adverse impact of climate change is enhanced by extreme water level fluctuations and human factors such as environmental pollution from waste water discharge, large scale agriculture and shoreline constructions reducing or eliminating valuable wetlands. Since eutrophication is a leading cause of impairment of freshwater ecosystems, specific strategies to address a lake's nutrient enrichment must focus on activities in the watershed and, if needed, in-lake restoration techniques. Analyzing the key factors of sustainable local and regional development in the vicinity of lakes, assessing the environmental risks of pollution, large scale agriculture, waste management and energy production, we propose a complex, stakeholder based management system and holistic regional development in lake areas, which will preserve natural ecosystems without compromising the sustainable use of ecosystem services. There are available technologies to develop ecologically acceptable water level regulations, promote organic agriculture applying grey water irrigation, stop leachate from landfills and control invasive species. Regional and local production and use of renewable energy is essential both for environmental and economical sustainability. Renewable energy production should be well coordinated with agriculture, forestry, waste management and management of water resources of lakes and their watershed areas in a sustainable, holistic way through a participatory approach. This is particularly pronounced in connection with tourism as one of the main uses of lake-ecosystem services, but also an environmental risk for natural ecosystems when mass tourism and short-sighted profit are the driving forces.

Introduction

Water quality of lakes and watercourses is a critical factor in the successful management of natural resources. Poorly managed water will have a negative impact on the quality of the environment, agriculture, irrigation systems and the

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aesthetic values and standard of touristic facilities. Lake management should include the mitigation of climate change, which interacts with many anthropogenic factors to shift the biodiversity, physical and productivity baselines of food and agro-ecosystems and the structure of aquatic habitats. Even for inland lakes, cross-sectoral interventions are vital to mitigate and also provide adaptation to climate change including the following: improvement of watersheds, to stabilize hydrological regimes and to increase aquatic and terrestrial vegetation without compromising biodiversity; keeping wetlands wet, to reduce greenhouse gas emissions; maintaining freshwater connectivity of wetlands and utilizing their ability to act as natural filter systems protecting surface waters from contaminants (Björk, 1979; Crisman et al. 2005). This is essential for providing the lead time necessary to take full advantage of opportunities for minimizing or adapting to impacts, as well as for allowing adequate opportunity for the development of the necessary institutional and financial capacity to manage change. The ecosystems of lakes and their watershed areas will not be able to adapt to and mitigate climate change successfully without greatly increased investment for research on aquatic biodiversity at all levels (gene, species/population and ecosystem), as well as for policy-making and for building the institutions and human capacities to implement the best science available. Furthermore, the effective and efficient management of lakes requires a holistic management structure built on self-sustaining ecological cycles and the sustainable use of ecosystem services put into the context of economical and demographical conditions of sustainable local and regional development strategies. We propose to develop methods for renewable energy based sustainable micro-regional development, ecologically acceptable water level regulations, promote organic agriculture applying grey water irrigation, stop leachate from landfills and control invasive species. Tourism facilities for the so called “second line” villages should be developed such as country tourism, health and spa tourism, agro-tourism and special tourism (even tourism for purposes of environmental education) to protected areas in order to take advantage of ecosystem services provided by the lakes and their catchment areas in a sustainable way.

The hydrological system and water level fluctuations, the impact of climate change

Dynamic changes in water level are controlled by the balance between inputs and outputs of water, which are in turn controlled by the hydrological processes. Many hydrological processes are sensitive to changes in climate. For example, during a prolonged drought, precipitation inputs generally decrease and evaporation outputs increase, resulting in a drawdown of lake level or even a complete drying out (Bond et. al. 2008). Climate also affects the lake water balance by changing the amount of stream flow and groundwater flow into the lake, but the response of the hydrological processes to climate is complicated because of the complex interactions among climate, vegetation, soil, and groundwater. Such interactions are also strongly affected by land-cover change caused by natural (e.g., fire) or anthropogenic (e.g., agriculture) processes.

Since water-level changes in ponds and lakes occur as a result of the water input exceeding output or vice versa and these are controlled by hydrological processes, understanding the water-level changes and resulting ecological responses requires understanding the individual processes. It is particularly important to realize the intimate link between lakes and their catchments (Armas et al. 2013). Disturbance in the catchment, such as major land use change (Foody, 2002), can cause a dramatic change in hydrological processes, which ultimately affects the lake water level such as the artificial drying out of wetlands, regulation of streams and rivers connected to a lake, ground water usage, intensive agriculture, etc. (Coops et al. 2003; De Vicente et al. 2006; Dinka et al. 2004). Climate changes also have major effects on water level. Ecohydrological linkage between plants and water presents a fruitful opportunity for collaboration between ecologists and hydrologists. The role of riparian trees in evapotranspiration and groundwater exchange, for example, is an important but relatively poorly understood process, which may provide valuable management tools in the future, because collaborative research on ecohydrology will enable us to observe hydrological processes and ecological responses simultaneously and to develop coupled models for the prediction of ecosystem responses to land use and climate changes (Formayer, 2006).

Water-level fluctuations are among the major driving forces for shallow lake ecosystems. The regulation of water level of shallow lakes is needed for reducing risks of flooding and economic purposes, including maximum agricultural benefit. The fixation of water levels may have a severe impact on the functioning of (semi-) aquatic ecosystems. There are some benefits of natural water-level fluctuations, considering the impacts on nutrient inputs, nutrient concentrations, phytoplankton development and turbidity (Carper and Bachmann, 1984; Kristensen et al. 1992; Bloesch, 1995; Bjelke, 2004). Shallow lakes are also sensitive to changes in wind force and direction, since sediment resuspension can increase turbidity (Aalderink et al. 1984).

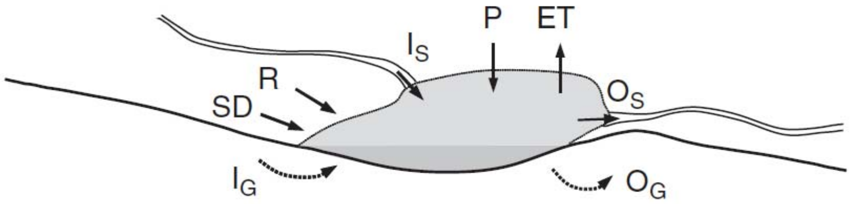

Figure1. *Schematic diagram showing water-balance components: precipitation (P), evapotranspiration (ET), stream inflow (IS), stream outflow (OS), diffuse runoff (R), snow drift (SD), groundwater inflow (IG), and groundwater outflow (OG). Source: Kamp & Hayashi, 2007.*

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In particular, the mediating role of submersed and emergent vegetation and filter feeders should be addressed. Policies, which allow more space for water, present a major challenge for combining flood prevention measures and ecological restoration.
Restoration of natural water-level regimes, which is likely to lead to enhancement of water quality and biodiversity, may occur in two ways: (1) expanding the critical limits between which the water level is allowed to fluctuate annually, and/or (2) incidental recessions of the water level. It must be emphasized, that ecologically-based water-level regimes should be incorporated into the context of multiple use of lakes. However, extreme water level changes often due to draught or floods may be particularly detrimental on shallow lake ecosystems. Therefore, restoration and/or construction of wetlands and water buffering reservoirs linked to major watercourses and secured by the filtering effects of wetlands might be necessary in certain areas (Molnar and Kutics, 2013).

Sustainable agriculture and management of agro-ecosystems and natural ecosystems of lakes, their watershed areas and sustainable reuse of wastewater for irrigation

Intensive agriculture in the vicinity of lakes may have severe impact on water level, water quality and biodiversity of limnic and semi-aquatic ecosystems. Nutrient enrichment of surface water bodies is often attributed to nonpoint source pollution from agricultural production areas where applied fertilizer has been leached from the point of application. Where this enrichment results in eutrophication of the water body, environmental and/or economic burdens are placed on society to live with or rectify the situation. In a number of places, intensive row-crop agriculture dominates land use in river and lake basins. Detailed, long-term studies of water quality in these water bodies are required in order to reveal high unit-area P loads, possible impacts of high level of gross erosion, concentrations of nitrate-N and the impact of currently used herbicides and pesticides, particularly from April through July (in the Northern hemisphere), both in surface waters and in public water supplies derived from the lakes and their watershed areas. To separate weather-related from management-related effects, an ecosystem approach should be applied. Agro-ecosystem management programmes aim to reverse land degradation in order to generate local, regional and global environmental benefits resulting from a more productive and sustainable use of biodiversity and agricultural ecosystems. They respond to the need for concerted action among farmers, communities, districts in the surroundings of the lake basin and the watershed areas to reverse the process of degradation and ensure the conservation and sustainable use of land, water and biological resources. Particular attention should be paid to the biodiversity of natural ecosystems and agro-ecosystem functions on which human livelihoods and food security depend. The goal of coordinated management of the natural resources of lake basins and watershed areas through the widespread promotion and adoption of productive and sustainable land management techniques is to ensure economically and ecologically sustainable farming and food security,

which is intimately linked with the multiple use of lakes. This integrated management system has four components to be implemented on the basis of an integrated ecosystem approach:
- enhanced regional collaboration, research, information sharing and monitoring;
- enabling policy, planning and legislative conditions;
- increased stakeholder capacity and knowledge at all levels for promoting integrated agro-ecosystems management;
- adoption of improved land use systems and management practices generating improved livelihoods and environmental services.

For the protection of lake ecosystems and their watershed areas all waste waters from different sources should be treated properly and, if possible, re-used for crop irrigation in agriculture. Shortage of economically effective and ecologically sustainable water sources for irrigation with suitable quality indicators in agricultural regions is an increasing problem worldwide. However, there are a number of sanitary and ecological concerns, which shall be taken into account in connection with the re-use of waste water. In many developing countries wastewater reuse in agriculture is an ancient practice that has been generally implemented worldwide. Agricultural deployment of wastewater for irrigation is based on the value of its constituents, which are used as fertilizers. Although crop irrigation with *insufficiently* treated wastewater may result in health risks (Simmons et al., 2010; Qadir et al., 2010; U.S. EPA, 2013), waste water can satisfy some quality indicators as chemical structure, availability of gases, content of organic substances and bacteria, muddiness, temperature, etc. Those indicators depend on salt tolerance of the cultivated crops, chemical structure and water permeability of the soil, drainage of the ground, characteristics of the rainfalls, background content of heavy metals, meteorological and hydro-geological circumstances, irrigation technology, applied agricultural techniques, etc. The suitability of the treated water for irrigation can be determined on the basis of results from chemical analyses, vegetation and field experiments, as well as comparing various crops irrigated with clean and treated wastewater during a longer period of time (Panoras et al. 2001). Thus, biologically cleaned waste water is a substantial resource. After biological cleaning, a simple sand filter system or other particle filters can remove particles – if needed – and low concentration of disinfectants will assure the appropriate water quality. This water should be almost entirely free of bacteria and can be used for irrigation. In agriculture it is possible to establish combined production structures, which include the use of bio-energy crops and forests as biological filters (root filtration), the application of biologically cleaned waste water, free from heavy metals, as crop nutrient through irrigation and the co-fermentation of waste water sludge and organic waste for production of bio-gas. For the safety of public health and the protection of groundwater and surface watercourses and natural habitats the environmental legislation in all developed countries require the thorough control and environmental consequence analysis as well as the systematic monitoring of the re-use of partially cleaned waste water (the "grey water"). The options for sustainable reuse projects are

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related to the quality of the effluent (Patterson, 2001), and the environmental risk associated with land application for a variety of crops and activities. As already mentioned by specifying some advantages, agriculture can be understood as a land treatment system as part of the treatment cycle and is considered as the nutrient recycling part of the loop. The soil as a bioreactor and its capacity to attenuate contaminants are taken into account. Nevertheless quality requirements of the treated wastewater used for irrigation purposes have to be met (Juanico and Shelef, 1994).

The other issue is the use of inorganic fertilizers in agriculture. Humans are currently fixing as much N_2 as the biosphere through the Haber-Bosch process for fertilizer production. The nitrogen emitted extensively by industrial companies has increased the nitrate and nitrite supplies in soil and water as a consequence of reactions that take place in the nitrogen cycle. Nitrogen pollution affects many types of aquatic ecosystems, including freshwater, brackish, and coastal marine environments (Driscoll et. al. 2003). Anthropogenic N and P flux can lead to eutrophication, which in turn promotes algal blooms (some of these species are toxic); bacterial decomposition of the decaying biomass results in depleted O_2; and both these effects have tremendous impact on fish and invertebrates in the system. High nitrogen concentrations may also contaminate drinking water supplies such as ground water and surface waters. Heavy use of nitrogen fertilizers in agricultural areas causes runoff into waterways, which leads to nitrogen pollution, which causes changes in the composition and functioning of aquatic ecosystems and contributes to long-term declines both in fresh water and, where appropriate, coastal marine fisheries (US. EPA, 2002) and biodiversity. Nitrogen fertilizers contribute to the acidification of freshwater, cause extreme plant growth, and can accumulate to toxic levels. The appropriate use of “grey water” could be an alternative to inorganic fertilizers together with the use of nitrogen fixing cover crops, precision organic agriculture, permaculture systems and in aquaponics in order to create sustainable ecological cycles.

Constructed and/or reconstructed wetlands may constitute another very efficient way of waste water treatment, mostly after previous treatment of black water. Nature-based wastewater treatment technology uses mainly natural processes and energy sources. The methods aim to reinforce natural self-cleaning processes. Soil, vegetation, ponds and processes occurring in these ecosystems are utilized for purification purposes. Constructed wetlands are artificially created ponds, resembling natural marshes or bogs, with a coarse media to support aquatic vegetation over an impermeable barrier, using the same processes that occur in natural wetlands. Some of these systems have been designed and operated with the sole purpose of treating wastewater, while others have been implemented with multiple-use objectives in mind, such as using treated wastewater effluent as a source for creation and restoration of wetland habitat for wildlife.

Solid waste management

Solid waste management is one of the biggest challenges of sustainable environmental management. The ecology of watercourses, wetlands and lakes depend on sustainable solid waste management as a number of factors such as at source sorting, waste composition, public behaviour, safe storage, recycling, landfill leachate to ground water, waste incineration practices, etc. determine the discharge of contaminants to the environment. Waste generation increases with population expansion and economic development. Improperly managed solid waste poses a risk to human health and the environment. Uncontrolled dumping and improper waste handling causes a variety of problems, including contaminating water, attracting insects and rodents, and increasing flooding due to blocked drainage canals or gullies. In addition, it may result in safety hazards from fires or explosions. Improper waste management also increases greenhouse gas (GHG) emissions, which contribute to climate change. Planning for and implementing a comprehensive program for waste collection, transport, and disposal (as little as possible)—along with activities to prevent or recycle waste—can eliminate these problems. Integrated Solid Waste Management (ISWM) is a comprehensive waste prevention, recycling, composting, and disposal program. An effective ISWM system considers how to prevent, recycle, and manage solid waste in ways that most effectively protect human health and the environment. ISWM involves evaluating local needs and conditions, and then selecting and combining the most appropriate waste management activities for those conditions. The major ISWM activities are waste prevention, recycling and composting, combustion and disposal in properly designed, constructed, and managed landfills. However, one of the most important goals of waste management should be the reduction or elimination of landfills to come as close to a zero waste society as possible through waste to energy programmes, recycling and Life Cycle Assessment (LCA) applied in product design and production.

Renewable energy

The most important lakes and their watershed areas are not only important touristic destinations, cultural centres and national parks but there are a number of domestic industries, service providers and agricultural enterprises, all of them energy consumers. Energy production accounts for a number of adverse environmental impacts on ecosystems, therefore the use of environment friendly, renewable energy sources is imperative. The production and use of renewable energy (with particular emphasis on bio-energy, solar power (solar collectors and photovoltaic), wind and geothermal energy) is the key for all aspects of sustainability, including economical viability. Agricultural lands occupy 37% of the earth's land surface. Agriculture accounts for 52% of methane and 84% of global anthropogenic nitrous oxide emissions. The best way to reduce these greenhouse gases is the substitution of fossil fuels for energy production by agricultural feedstocks (e.g. crop residues, dung and dedicated energy crops) and other renewable energy sources. In agriculture it is possible to establish combined production structures, which include organic, chemical-free crop production, the use of bio-energy forests and other

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dedicated energy crops as biological filters, the application of biologically cleaned waste water, free from heavy metals, as crop nutrient through irrigation and the use of waste water sludge and fermentable organic waste for production of biogas. Dedicated bio energy crops may increase the soil carbon sequestration, hereby contributing to the reduction of global warming. In this way complete ecological cycles can be created, which utilize all energy sources in an optimal way and minimize waste production in order to create ecologically and energetically self sustaining societies. Between 2006 and 2011 the production of new renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels) increased; changes in renewable energy markets, investments, industries, and policies have been so rapid that perceptions of the status of renewable energy can lag years behind the reality and growing further, very rapidly (REN21, 2011). Global energy consumption rebounded in 2010 after an overall downturn in 2009. Renewable energy, which experienced no downturn in 2009, continued to grow strongly in all end-user sectors – power, heat and transport – and supplied an estimated 16% of global final energy consumption. Renewable energy accounted for approximately half of the estimated 194 gigawatts (GW) of new electric capacity added globally during the year. Renewables delivered close to 20% of global electricity supply in 2010, and by early 2011 they comprised one quarter of global power capacity from all sources (REN21, 2011).

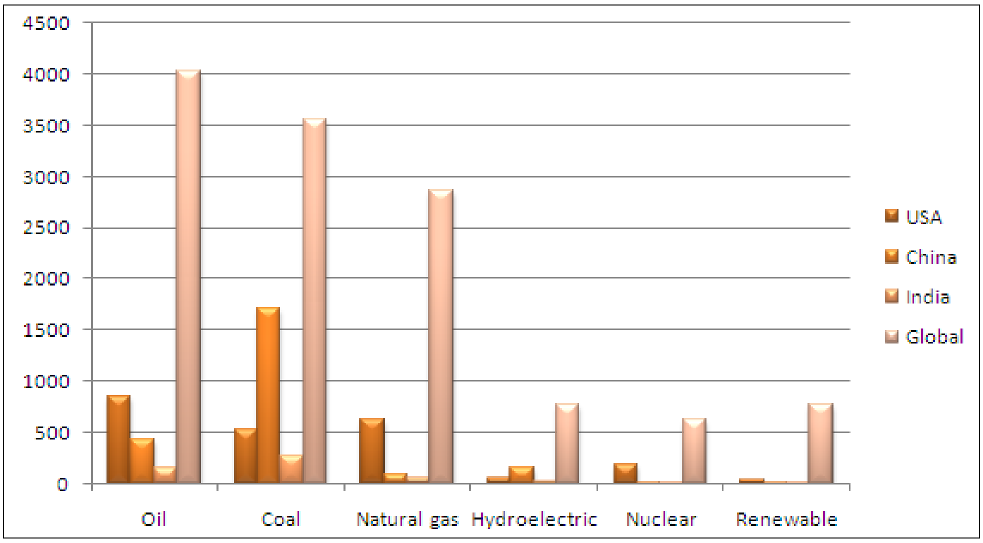

Figure 2. *Energy consumption pattern (in million tonnes oil equivalent). Source:* BP statistical review of world energy 2011.

According to the Global Status Report for the year 2011 by the Renewable Energy Network for the 21st Century (REN21) even countries with traditionally high fossil fuel consumption substantially increased the share of renewable energy in their total energy production (Fig. 2).

Integrated food-energy systems: a holistic, sustainable solution

Most of the world's energy-poor people live in rural areas and rely on agriculture for their livelihoods. For many developing countries seeking greater energy security, agriculture provides the greatest opportunity for sustainable economic development. While biomass has been – and continues to be – the primary energy source for the rural poor in developing countries, it has also been of special interest in the Organisation for Economic Co-operation and Development (OECD) countries in recent years, mainly due to the production of liquid biofuels for transport. This has caused strong controversy, mainly regarding the potential risk that the production of biofuels may pose to food security of the rural poor in developing countries, but also regarding issues related to global climate change. For this reason, integrating and intensifying food and energy production has the potential to improve food and energy security in rural villages and the national level as well. In addition, developing systems that integrate bioenergy and food production can play a large role in making agricultural production 'climate-smart'. Small-scale farmers are globally the largest farmer group and of key importance to local and national food security in developing countries (Fig. 3).

Therefore safely integrating, intensifying and thus increasing food and energy production for this large group of producers may have the best prospect to improve both local (rural) and national food and energy security and reduce poverty and environmental impact at the same time. The renewable energy generated through these systems can reduce the need to burn expensive fossil fuels: a main source of greenhouse gases. Such systems also increase the productivity of land and water resources, easing pressures to clear forested areas and damage other natural landscapes for agriculture or other purposes. In this way, these systems can be an effective approach for mitigating climate change because changes in the way land is used are another important source of greenhouse gas emissions. They can also contribute to climate change adaptation. Farming communities that are more energy self-sufficient and that spend less for agricultural inputs are more resilient and better able to cope with change. In a holistic integrated food and energy system there is no conflict between bio energy production and food supply, the ecological footprint is sufficiently small. A transition is needed from fossil fuel centred, ineffective and inefficient societies to the ecologically and economically viable, recycling society. Under less favourable conditions the (regional) bioenergy potential(s) could be quite low. In addition, it should be noted that technological developments (in conversion, as well as long-distance biomass supply chains such as those involving intercontinental transport of biomass-derived energy carriers) can dramatically improve competitiveness and efficiency of bioenergy (Hamelinck et al. 2004; Faaij 2006).

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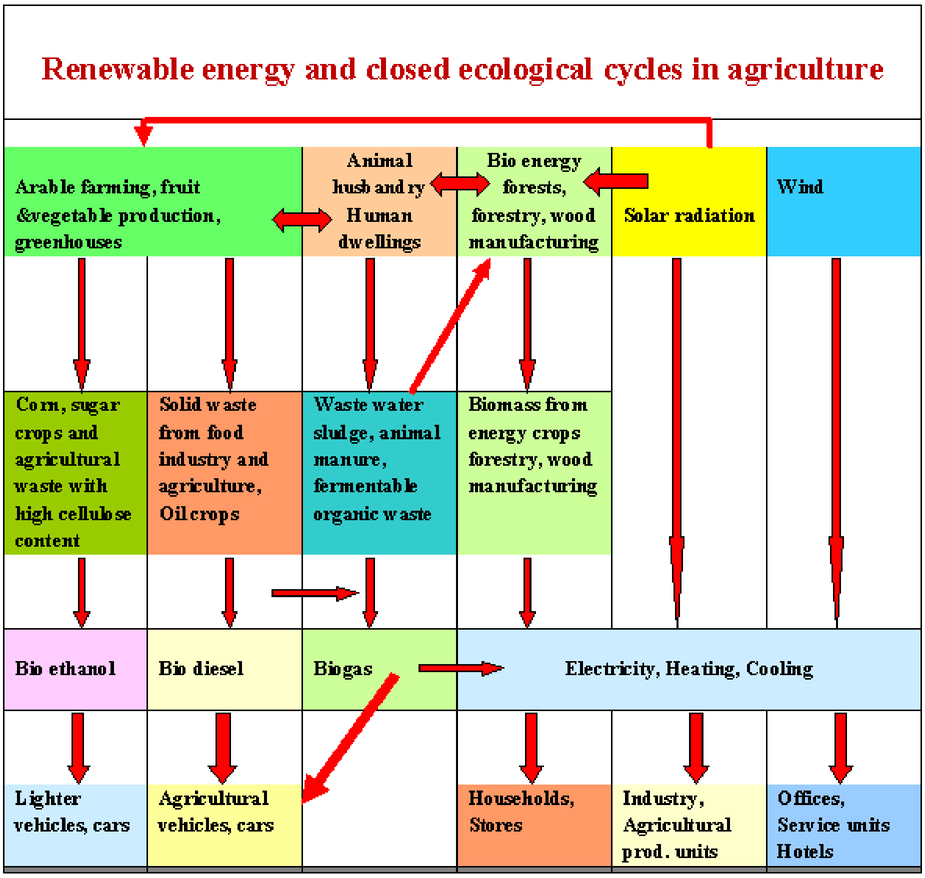

Figure 3. *The material and energy flow in sustainable integrated food-energy systems (S. Némethy).*

Sustainable tourism

Sustainable tourism is travel and local/regional hospitality services designed to minimize the impact of humans on the places they visit, encourage protection of both cultural heritage and the environment and provide long-term, socially just economic opportunities for local residents. Many lakes are important tourism destinations – or should become part of a sustainable tourism development. Economic, social and environmental aspects of sustainable development must include the interests of all stakeholders including indigenous people, local communities, visitors, industry and government. Therefore the main focus within tourism development strategies should be the stay, services and activities at the destination and its surroundings within the framework of with each other compatible local, national and transnational strategies, where cooperation between tourism organizations and authorities both on national and international level facilitates a sustainable tourism development (Manning & Dougherty, 2000;

Némethy, 2013) taking into consideration the adverse environmental impact of mass tourism, tourism transport (access to destination and return travel, local mobility in the destination), carrying capacity (land use, biodiversity, tourism activities), use of energy, use of water, waste water purification, solid waste management, social and cultural development, economic development and institutional governance. Furthermore, many lakes or parts of lakes and their watershed (marshlands, bird sanctuaries) are also protected areas, important resources for conserving biodiversity. At present approximately one tenth of the world's land surface is a protected area in some form. Sustainable utilization of wetlands and lakes is determined by the perceptions/attitudes of fishermen, agriculture, local population and tourists who are the main users of lake resources. Successful implementation of conservation policies, management measures and environmental education programmes requires consideration of those attitudes and resolution of the conflicts between humans and the natural environment. As identified by the IUCN protected areas have various management styles which include:

- strict protection: a) strict nature reserve and b) wilderness area;
- ecosystem conservation and protection (i.e., national park);
- conservation of natural features (i.e., natural monument);
- conservation through active management (i.e., habitat/species management area);
- landscape/seascape conservation and recreation (i.e., protected landscape/sea scape)

Protected areas constitute the basis of the majority of conservation strategies, both nationally and internationally, in order to maintain natural ecosystems in an attempt to prevent threatened plant and animal species from becoming extinct. Therefore new protected areas need to be established in the future which will capture these threatened species. Tourism within protected areas is the vehicle by which park managers come into greatest direct contact with society, and it provides a rich opportunity for explaining park values, ensuring their ongoing existence and directly contributing to human welfare through the reflective and active recreation opportunities they provide.

Conclusions

A holistic approach in integrated activities, taking into account the joint resources of overlapping areas, is imperative to use these resources in the most effective and efficient way by linking bio-energy production, wastewater purification, solid waste management, food production, animal husbandry, the production of biogas and grey water irrigation.

For shallow lakes, water level regulations as means for mitigating the adverse effects of climate change should be planned taking into account existing ecosystems and ecosystem services.

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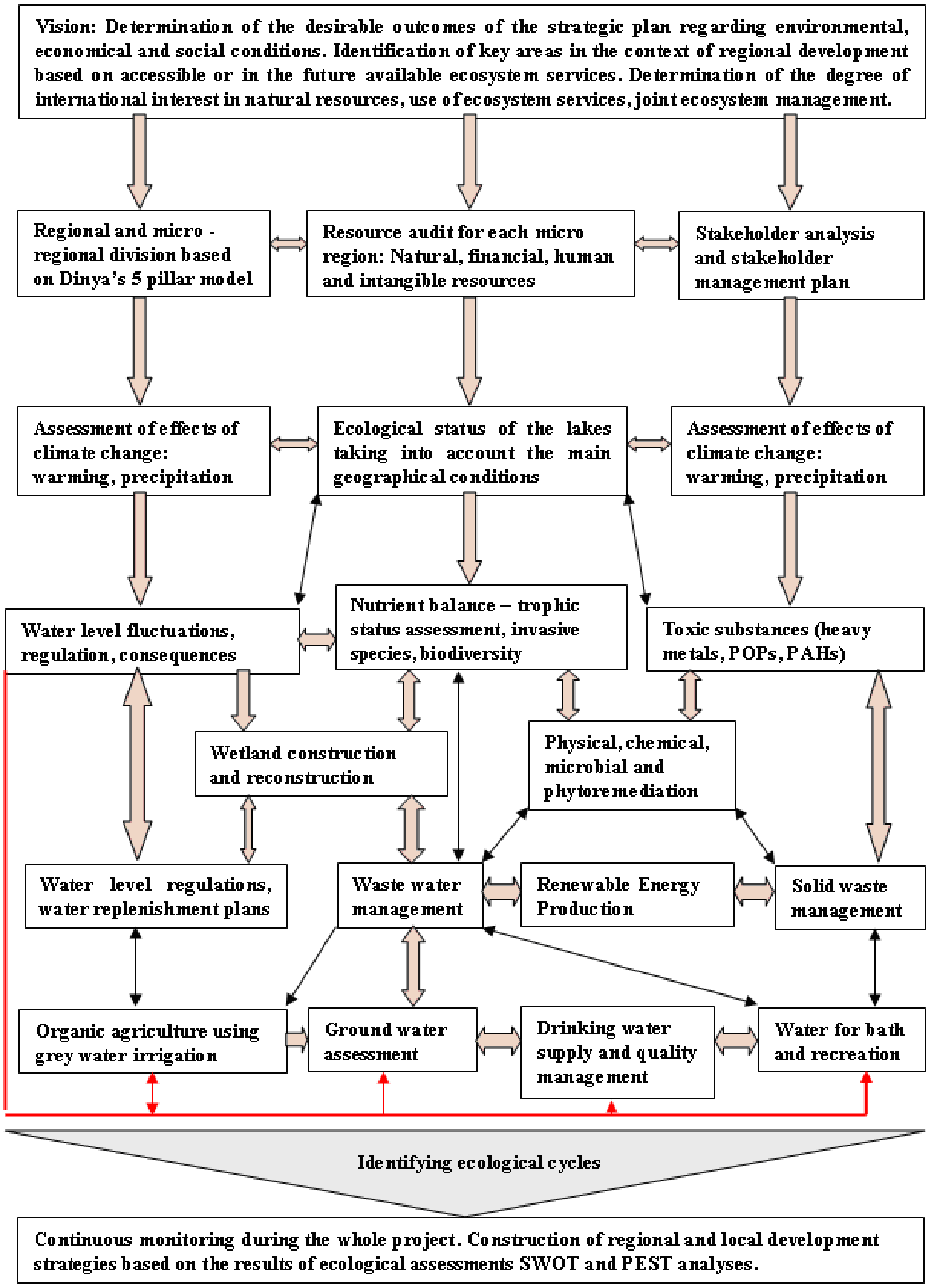

Figure 4. *Lake management strategy implementation flow chart, which is applicable both for transnational strategies and regional/local management, depending on the location of the lake (internationally shared water), the stakeholders and the scope of development projects (Némethy & Molnár, 2013).*

Sustainable solid waste and wastewater management based on recycling and re-use will reduce/eliminate the sources of pollution and eutrophication.

Bioenergy is one of the most sustainable forms of renewable energy. Agriculture and agriculture related industries can provide a range of feedstocks such as woody and other cellulose containing biomass, crop residues, oil seed crops, fermentable wastes (including waste water sludge), and animal manure for bioenergy.

Ecosystem management (control of algae, water quality and water level and control of import) may reduce the risk for invasive species by favouring the ecological conditions for the indigenous ones

For a successful strategy, stakeholder analysis and stakeholder management plan is essential, it is a prerequisite for strategic planning and the implementation of strategic plans considering the fact, that the power of certain key stakeholders and stakeholder groups may facilitate or block development or even environmental management plans regardless of their objectives if a real or assumed conflict of interests occur.

Larger, heterogenic areas around the lakes should be divided into manageable, more homogenous micro regions according to the five pillar model (Dinya, 2011, 2012), because this concept enables the implementation of strategic plans through cohesive socio-economic structures better logistic, easier applicable control mechanisms and communication.

Well maintained ecosystem services will favour tourism development, particularly health, recreation and rural tourism and the educational aspects of special interest tourism.

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