SUSTAINABLE DEVELOPMENT OF FORESTRY AND CONSTRUCTION OF SMALL HYDRO-POWER PLANTS IN BOSNIA AND HERZEGOVINA

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The idea of sustainable development is clearly reflected in the fact that the growth of human population is one of determinants of the development of human civilisation and social system on our planet. On the other hand, this development comes at a cost of exploitation of another system – natural (space and resources), which is yet to become an issue in the future. It remains a fact that the human population cannot be denied of this right, but the range and manners of this exploitation should and must be challenged.

The fact that this process is an excessive one is evident from the fact that the natural balance is being more and more endangered, with one of the most topical issues being deforestation in the geographic layer. With regard to this, the issue of protection of forest complexes and forest ecosystems is a multi-layered one, where the construction of small hydro-power plants (SHPP) is one of major challenges.

The research is based upon the fieldwork of authors at the sites of numerous watercourses in Bosnia and Herzegovina, as well as on a detailed analysis of meteorological, hydrological, and bio-geographic data concerning the basins of rivers of Vrbanja and Velika Usora respectively. Due to the disturbance of the balanced specific flow in the basins, there are records of forestsć vulnerability, increased risk of erosion and occurrence of high and low waters.

Key words: sustainable development, forests, small hydro-power plants (SHPP), water regime, erosion.

INTRODUCTION

The roots of the ever-growing crisis, caused by exploitation of natural resources, lie in the range of socio-economic development and the way the majority of human population transform natural capital into private capital, that is, into satisfying their own living needs (quality of life). The fact that the uncontrolled exploitation of natural capital is becoming the manner of behavior of the modern-day human, is reflected in the fact that the amount of resources used at the global level in the 1950 – 2010 period matches the one used by all previous generations.

Classic resources, i.e. resources whose exploitation relies on the technology available today, can only provide as much energy as for another 30 years (Ristic, 1995). Environmentalists, economists, ecologists, and many other experts have been warning for long time now of the fact that negative changes afflicting the environment are the result of the efforts of human population to secure the highest possible living standard, regardless of the price tag it comes with. M. Djukanovic (1996) claims that the quality of life of human population and the quality of the environment are closely related, but that they are not reciprocal. In their effort to secure their own quality of life, humans do it at the expense of the quality of the environment. That way, the environment, which develops spontaneously, by means of self-regulation, progressively decreases its potentials due to the excessive exploitation by human population. Further uncontrolled economic and spatial pressing of our civilisation on nature depends partly on the fact to what extent humans are going to accept the assessment of their own development without any sense of criticism. At the beginning of the third millennium, overall efforts of human population to constantly advance the quality of life cannot be realised any more on the principles of unlimited exploitation of resources and unlimited assimilative capabilities of nature to absorb anthropogenic emissions of matter and energy. It is not possible for human population to destroy forests, hydrospheric, and pedospheric complex at any given geographic area without that loss not being reflected momentarily and permanently on the GDP of a certain administrative-territorial unit. The contemporary assessment of economic development does not include the valorisation of ecosystems i.e. are maintenance of land quality, forming of aquifers, preservation of fresh air, and regulation of microclimate. Their loss often leads to great expenses and reduction of GDP. With regard to this logic, if the development of any regional or local segment is expressed solely in terms of GDP, the creators of such a model of development can easily deceive the human population by saying that '*so far, we have had a quick and successful development, but now we have run out of forests and fresh water'*.

With the technological revolution at the turn of the millennium, the inventory list of our planet shows that we already live in numerous degraded and devastated geographic areas, with landscapes, rivers, forests, and lakes irreversibly ruined, that we are faced with a possibility of fresh water reduction and global climate change. Thus, one can conclude that the greatest global challenges are the following: possible climate change caused by energy issues, deforestation and possible rise of sea level, damage to the ozone layer, hazardous waste, and endangering of biodiversity. Furthermore, there is a possibility of destruction of biosphere and its ecosystems, global degradation of the environment (of all geo-components), great demographic growth in some geographic areas and depopulation in others, as well as exhausting all kinds of resources.

2. SUSTAINABLE DEVELOPMENT

One finds it logical that the degradation of the environment and exploitation of its resources is limited, resulting in the development of the planet being defined as 'sustainable (harmonised)'. The phrase *sustainable development*, established in 1989 and proclaimed by the so-called Bergen Declaration in 1990, denotes a possibility of further development of not only the present generation of human population but of future ones as well. The term *sustainable* (adopted in Rio de Janeiro in 1992) emerges, most likely, out of necessity of sustainably exploiting resources, that is, out of necessity that every activity relying on exploiting resources must be maintained permanently. Even today, this term does not reflect real potentials of numerous resources, in the first place fossil fuels, hydrospheric complex, and, to the greatest extent, forests. It is a known fact that the economic growth promoting

GDP has been the main goal of economic policy creators at both the local and global level, expressing their wish for the upgrading of the living standard of human population by placing goods and services on markets worldwide. Accordingly, this has negative consequences for the environment, sending a clear message that economic growth does not provide an adequate perspective for permanent advancement of living standard. Essentially, one of the key determinants is an analysis of the global development conceived this way, since many traditional societies have been devastated by it. (Kupusovic, 2016).

It is evident that the wish for faster economic growth has exerted negative influence on the environment, especially in urban geographic areas of the developing countries. The consequences were visible in degradation of numerous ecosystems, with forest ecosystems being the most vulnerable ones. As an answer to this, there has been 'new development concept introduced – the concept of sustainable development, which protects the environment and upgrades social justice' (Kupusovic, 2016).

According to M. Djukanovic (1996), sustainable (harmonised) development means that the present generations should plan and create the quality of the environment that suits their needs, leaving, at the same time, the future generations the very same choice. The philosophy of sustainable development is based upon the principle of inter-generation equality. If this principle is not respected, it means that the damage to the environment done today is passed onto the next generation. Some authors claim that the philosophy of sustainable development is related to the techno-economic approach to environmental issues within the socio-economic development as a whole.

3. SUSTAINABLE DEVELOPMENT OF FORESTS / FORESTRY

Forests, the type of vegetation that comprises herbal communities dominated by trees with more or less covered canopies, are one of the most significant factors of the economic development and preservation of the environment on our planet. In the wider sense, the forest is a natural-territorial complex singled out in both regional and typological terms as a wholeness of natural segments similar in their morphological and functional characteristics (Landschaft, taiga, etc.). According to some authors, forests constitute natural habitats with a surface area larger than 0.5 ha, canopy cover higher than 10%, and trees taller than 5m, featuring variable ground flora. They exert significant influence on the emergence of different land types in nature, the physical structure and thermal properties of land, as well as on the regulation of retention and movement of water in land and its availability to plants and aquifers. In essence, they modify climate over numerous geographic areas because they have enormous impact on their close and, in some cases, wider surrounding, depending on the surface area they cover and the height, density, and type of trees. With regard to this, it is crucial whether these are coniferous, deciduous, or combined forests (Rajčević and Crnogorac, 2011).

Forestry is an industry that comprises plantation and exploitation of forests, along with management of forest areas of specific purpose. With regard to the latter, this refers to forests and forest land, forest products (timber, bark, resin, fruits, etc.), natural goods that can be found in forest land (rock, sand, etc), as well as to other benefits offered by forests (protective, recreational, etc.) Uncontrolled felling of forests, causing, in most cases, erosion and torrents, represents a significant obstacle to the development of sustainable forestry. In case of building small hydro-power plants (SHPP), especially those that feature pressure water pipes, the consistency of forest land is disturbed by the great extent by the construction of road routes for transporting technical-material means and routes for pipes themselves. The stable base is transformed into unstable one, with water erosion removing the land from the basin for good, with emergence of numerous landslides. The research up to date have shown that water erosion turns basins of natural, mountainous watercourses into torrential floods in their lower sections. At the same time, this erosion, by producing enormous deposits, causes the occurrence of high waters in lowland rivers. In terms of protection against erosion, most effective forms are forestation and grass planting.

3.1. Forest complexes and groundwater

With regard to its exploitability, water, as one of the most important geocomponents of the geographic layer, is a sensitive and limited resource. Water resources represent a necessity in everyday life of human population, industrial and energy production, agriculture, etc. In a nutshell, water, in any of its aggregate states, is one of the greatest values of our planet. There is a series of factors that influence the quantitative and qualitative properties of water, and one of current challenges for water resources is forest exploitation, which has a direct impact on the quality and supplies of groundwater.
Thus, it comes as no surprise that the Agenda 2030 was adopted on the UN Conference on Sustainable Development in New York in 2015, with a view to protecting, establishing, and promoting sustainable exploitation of land ecosystems and sustainable forest management, to checking desertification, preventing land degradation, and, finally, preventing destruction of biodiversity.

The groundwater regime is, in its essence, the resultant of a series of complex and inter-dependent phenomena. Basic natural factors of this regime are climatic, geological, hydrological, and biological. Forests exert a special influence on precipitation (rain, snow) and feeding aquifers with water. The role of precipitation in forest areas is twofold: to provide plants with enough quantities of moist and the amount of water to infiltrate over a topographic area into aquifers. The exact amount of water to be infiltrated depends on the intensity and duration of precipitation, the properties of the land, the overall condition of the topographic area, the percentage of saturation, the decline of the topographic area, and the type of vegetation. In addition, one should neglect neither the season nor the stage of the vegetation development. It is common knowledge that plants retain a significant share of precipitation and influence the regime of aquifers, feeding watercourses with water, and forming water supplies for permanent springs.

For those reasons, it is not possible to adopt a unique numeric table with regard to the distribution of precipitation in forest areas. One part of it (rain) is retained in canopies and mostly evaporates into the atmosphere, one part drains off down trunks of trees, with the rest falling from branches, leaves, or needles in the form of drops.

The exploitation and elimination of forest cover is one of the most significant physical'geographical, as well as anthropogenic factor. This is reflected in the changes to the specific flow (q) of a certain river basin and the amount of water infiltrated into aquifers. In other words, it is forests that exert the greatest impact on the regular runoff of precipitation, surface waters, and the water penetrating through land (Dukic and Gavrilovic, 2006). With respect to this, it is canopies, fallen leaves, and pine needles that play the major role. The research so far have shown that plants most efficiently regulate the balanced runoff in forest land. Rational exploitation of forests contributes to protection against erosion, along with stable distribution of water to aquifers. Yet, in case of uncontrolled elimination of forest cover (road routes, grid routes, etc.) without any form of biological protection, such as forestation and grass planting, erosions and torrential floods are imminent.

The role of vegetation in the precipitation run-off

Vegetation (lat. vegetatio) represents a range of all herbal communities of a certain area of the Earth's surface. In humid (moist) areas, where there are records of erosion and torrential floods, vegetation is primarily represented by forests, and secondarily by meadows, pastures, cultivated land etc. Based on long-term detailed studies of the impact of vegetation on the runoff of precipitation, it can be concluded that this impact, as a hydrological factor, is often the crucial one for the groundwater and surface waters regime respectively (Rajcevic and Crnogorac, 2017).The conclusions are as follows:

- the overall number of herbal species that can be found in a certain geographic area contributes significantly to balancing water regimes by absorbing certain amount of precipitation and by increasing infiltration;
- based on experiences from meteorology, it is a known fact that forests, to a certain extent, increase precipitation;
- due to keeping water on leaves and branches (interception), vegetation acts in the direction of reducing the overall mass of water running off from a certain basin;
- by creating loose land and by preventing it from being washed away by erosion, plants protect aquifers;
- the impact of vegetation is evident in preventing erosion processes, then in slowing down and preventing deposits from endangering watercourses or from accumulating in lake basins;
- snow cover in forests, by gradually melting, contributes to feeding watercourses with water; it is estimated that there is 18-20% more snow in a forest than on a bare stretch of land;

'Forest felling and cattle grazing disturb the surface structure of soil and worsen infiltrational capabilities of land, which is reflected in the change of the value of water balance and water regime elements'. (Dukic, 1998).

Above all, forest felling is one of the most significant negative anthropogenic factors concerning weather and climate today. Over the course of centuries, this human activity across vast areas has led to turning deciduous forests of the temperate zone, featuring their own climate, into a cultural steppe with another climate, with a series of variants of micro-climate, without even being aware of that.

In mountainous areas, by means of clearing out forests, humankind has completely altered micro-climate, that is, contributed to erosion and changed the values of components of water balance (Dukic, 1998).

SMALL AND MINI HYDRO POWER PLANTS AND SUSTAINABLE FOREST DEVELOPMENT

The analyses following destructive floods that struck Bosnia and Herzegovina in 2014 resulted in rather pessimistic forecast regarding flood risk for the future period. Floods can still exert extremely negative consequences for the population and material means, unless some basic principles are timely defined. Accordingly, protection against the harmful effects of floods is by no means a priority that needs to be harmonised with the rank and quality of the projects realised by urban, economic, infrastructural, and other systems that require such protection against high waters. This approach is a result of a common principle that the protection of an area is a dynamic category and that it changes depending on the extent to which the designated systems are endangered, as well as depending on the new approach to hydrological data processing, on morphological changes to the basin, and on changes concerning river regimes. By doing so, it is necessary to decide upon the adequate level of protection, where designing technical documentation is the first step to be taken. Understanding the nature of high waters is very important in terms of calculating the scale of hydro-technical objects and cost-efficiency of build-off, as well as in terms of security measures.

The river basins in Bosnia and Herzegovina have suffered severe deforestation, mainly in the form of felling, which resulted in the disturbance of regular runoff in forest and agricultural land. This also led to the occurrence of erosion and torrents in the geographic area of Bosnia and Herzegovina, i.e. this led to the disturbance of the natural balance between vegetation, land, and specific runoff. Due to massive and uncontrolled forest felling, abundant precipitation and snow thawing initiate rapid occurrence of great waters, that is, changes to the specific runoff in the basins suffering the most with regard to this issue. The impact of forests on the change of specific runoff is especially visible in the areas where there are SHPs.

The specific runoff (q) represents a number of litres of atmospheric water that runs off from the surface area of a basin expressed in km^2/s, and it is an adequate unit for hydrologically studying rivers. The ratio between absolute maximum and minimum flows (Q) and their respective specific runoffs (q_{max}, q_{min}) is presented on the example of the River Vrbas and its greatest sub-basin, the River Vrbanja, in Table 1.

One of the priorities of potamologic research is studying river regimes and singling out and classifying their types and variants. M. Parde, a French hydrologist, points to the fact that ‘the regime represents a complex of phenomena that refer to feeding watercourses with water and changes in their conditions’. There are following types of river regimes, based on the manner rivers are fed with water: nival, pluvial, nival-pluvial, pluvial-nival, etc. In most cases, they are combined, with the dominance of one source of feeding for different sections of river flow and for different seasons.

Table 1. Relation between (monthly/yearly average) maximal and minimal flows (Q) and their specific runoffs (q) in the Vrbas River basin (year 2010 - 2015)/

River	Location	Sliv, km^2	$Q_{max,}$ m^3/s	$q_{max,l,s,}$ km^2/s	$Q_{min,}$ m^3/s	$q_{min,l,s,\ km}{}^2/s$	Odnos 4:6	Odnos 5:7
1	2	3	4	5	6	7	8	9
Vrbas	B. Luka	6386	1313	0.2556	22.2	0.003476	59.14	59.125
Vrbas	Delibašino selo	6386	1324	0.2073	13.8	0.002161	95.74	95.93
Vrbanja	Vrbanja	791.33	843.8	1.0663	0.7	0.00088	1205.4	1211.70

SHPPs and river regimes

Definition of river regime

One of the essential priorities of the objectives and the study of river research is the study of water regimes, the separation and classification of their types and variances. The French hydrologist, M. Parde, points out that "the regime represents a complex phenomenon related to feeding waterways and changes in their condition". The river regime is a consequence of the feeding of the river with water, according to which the following types of river regimes are distinguished: nival, pluvial, nival-pluvial, pluvial-nival, etc. The most common combinations are river regimes with predominant importance of one feeding source for certain parts of the river stream and in different periods of the year.

Current water level and water level over a monitored period of time

The current water level represents the height of water level on rivers, lakes, and seas in relation to some arbitrary horizontal surface, and it is monitored and measured for the purpose of sailing, designing and building off various hydro-technical objects (ports, watercourse regulation, arranging the riverbed – deepening the riverbed, fortifying river banks etc.), constructing bridges, water accumulations, protection against floods etc.

Water flow

Due to potential and, in case of some watercourses, relatively frequent changes of water level as a result of alluvium deposits and deepening of the riverbed through increased intensity of vertical erosion, it is often not possible to determine the properties of river regimes. For that reason, hydrologists mostly rely on the change of the quantity of water flowing through the profile of a certain river, thus focusing on the flow rather than the water level. The flow is the amount of water passing through any section of the river over the period of 1(one) second. It is usually measured at locations where there is a water measuring stick, and it is expressed in m^3/s. The flow depends on precipitation, soil structure, relief, plants, and the size of the basin.

SHPPs and the environment protection

At the beginning of the 21st century, building off SHPs has been an industry on the rise in the entities of the Republic of Srpska and Federation of Bosnia and Herzegovina respectively, with more than 280 concessions granted (data from May 2016) for the construction of small and micro hydro power plants. They are built for the basic purpose of producing electrical energy, but their polyfunctionality should be clearly valorised within the concepts of water supply, irrigation, development of agriculture, fishery, recreation, and tourism, which has not been the case so far. In order for an SHP to be constructed, it is necessary to define the basic approach through an Environmental Impact Study (EIS), which implies harmonising the goals of the development, that is, sustainable development. This also implies the harmonisation of requests for optimal space usage, which, in turn, implies the application of the GEMS system (GEMS – Global Environment Monitoring System). With regard to Bosnia and Herzegovina, it can be concluded that renewable resources are still largely unused.

Spatial planning solutions and the role of MHPP in the environment

The major barriers in the process of constructing an SHP are the following: administrative, social, technical, financial, institutional, legislative, environmental, and ecological (EIS) With regard to administrative ones, non-issuing of urban permits and long deadlines for completing valid documentation discourage potential investors. By means of application of the GEMS system and the ISO 14001 approach, it is possible, to a great extent, define the influence of SHPs on the environment of Bosnia and Herzegovina.

Temporary and permanent impacts of construction of hydro power objects with respective accumulations. Temporary impacts (lasting from 1 to 3 years) are the following: increased level of noise in the zone of construction site, increased air pollution due to construction works and exhaust gases of the mechanisation engaged, and the visual change of landscape. These impacts are reflected on biodiversity (flora and fauna), as well as on the settlements and human population in the zone of construction site, where it is the penstock and the construction of engine facility that exert the greatest influence in this respect. When permanent impacts are concerned, the supposed ones are the following:

- New manner of exploitation of water masses is going to change the ecological picture of a certain geographic area.
- Forest felling and disturbance of sustainable management of forest and forest ecosystems.
- The change of the groundwater and surface waters regime respectively in the basins where SHPs are located.
- The visual change of landscape and potential changes of transversal profile of riverbeds and river valleys.

- Given a relatively small volume and surface area of the SHP in question, there will be little impact on meteorological parametres (temperature, air humidity, precipitation, winds etc.)
- Permanent impacts that can be felt in certain geographic areas, due to construction of road infrastructure (access roads to the construction site, access roads to the accumulation and engine facility sites, construction of the penstock and route for the power line, as well as possible induced seismicity (change of the groundwater regime).

Accident hazard. When designing an SHPP with a respective accumulation, it is necessary to define, through special annexes within each separate project and taking into consideration specific features of each watercourse, protective measures to prevent potential accidents. This refers both to the period of the build-off of the SHPP in question and the period of its exploitation.

Spatial planning solutions concerning the usage of watercourses in Bosnia and Herzegovina for construction of SHPs

According to the available up to date data, there have not been any activities aimed at valorising and verifying, in spatial planning terms, the basins of minor watercourses in Bosnia and Herzegovina, with regard to potential water management projects of constructing SHPs. It is evident that a set of complex (expert) documentation covering the river network of Bosnia and Herzegovina would present a solid basis for determining guidelines and terms of exploitation and protection of waters in all spatial planning activities. The water levels and flows of upper sections, and often of lower ones as well, of numerous watercourses are characterised by the waves of great waters with the occurrence of maximum daily flows, which endangers lower, wide sections of river valleys where SHPs are built. Levees and contour canals, built for providing protection against floods, as well as increasing the flow of the riverbed, are expensive and technically unfavourable solutions, due to their measures (the ratio between the length of the protective objects and the topographic area).

Given the aforementioned, our solution is regulating/leveling the flow at initial sections of the basin. Consequently, the strategy for providing protection against floods in the river basins of Bosnia and Herzegovina should be based on water accumulations, which absorb the impact of great waters. Due to a relatively short period of duration of maximum flows, significant effects concerning reduction of maximum flows can be achieved with relatively small retention areas and accumulations. By building multi-purpose accumulations, one prevents possible flooding, enables a more efficient and rational water supply system, electrical energy production, improves the water regime and the environment references, provides for the development of tourism and recreation, makes contribution to industries such as cattle-breeding, husbandry etc.

The natural values that are emblematic of the mountainous watercourses in Bosnia and Herzegovina can rarely be found in river networks outside our country. It can be stated that these are unique and pristine areas, featuring geomorphological properties (crags, canyons, speleological objects, composite valleys, geological values etc.) that much larger geographic areas in Europe are deprived of. The majority of watercourses for which there are concessions granted for the construction of SHPs feature an abundance of flora and fauna, varieties of landscapes with natural panoramic spots, and beautiful and breathtaking falls, rapids, and cascades.

Taking the examples of the rivers of Vrbanja, Studena, and Jalova, as well as many more where there are SHPs built, one can witness the devastating damage these objects inflicted on flora, fauna, and ichtiofauna and forest complexes, which leads to the extreme increase in values of the specific runoff and the occurrence of great waters in the basin.
By laying down the penstock, the existing riverbeds turn into dry riverbeds from the point where the dam is erected to the point where the engine facility is built (1.5 – 4.0 km, even longer), losing all their natural functions. Subsequent erosion processes turn the topographic area into ruts, gullies, ravines and, eventually, into badlands, rendering it inappropriate for any purpose in the following 20 or 30 years.

CONCLUSION

When designing and constructing SHPs (with respective accumulations), there are detailed records needed on the engineering-geological and hydrogeological properties of the basin, as well as on those regarding morphometry, morphology, hydrology, climate, geomorphology, pedology, and biogeography. Furthermore, geomechanical, geotechnical, geophysical, and geochemical characteristics are necessary. SHPs must be constructed in accordance with global standards and following the legislative acts of Bosnia and Herzegovina regulating this area. In the valleys of numerous watercourses where there are plans for the construction of SHPs, one can find a certain number of endemic species and relicts in the structure and texture of the rock mass, and they need to be protected. By putting SHPs and their respective accumulations to active use in terms of hydro energy production and other purposes (sport activities, recreation, tourism, fishery, irrigation, etc.), this geographic area would be enriched in both economic and spatial terms.

The existing engineering-geological, hydrological, and geomorphological data on the basin of the upper stream of the Sana show that this area is suitable in terms of building hydro power plants with respective accumulations. With regard to the aforementioned area, the process of karstification lags behind that of erosion, rendering an insignificant risk of accumulation forming. Furthermore, the research have shown that ground waters correspond with the riverbed. Overall, the physico-mechanical characteristics of rock masses within the geological structure of the terrain are suitable for designing hydro energy facilities. In addition, the lime-stone masses are stable and adequately waterproof. However, there is a possibility of the existence of less favourable local zones, but this, after a detailed research, can be overcome by means of design and constructionThe existing engineering-geological, hydrological, and geomorphological data on the basin of the upper stream of the Sana show that this area is suitable in terms of building hydro power plants with respective accumulations. With regard to the aforementioned area, the process of karstification lags behind that of erosion, rendering an insignificant risk of accumulation forming. Furthermore, the research have shown that ground waters correspond with the riverbed. Overall, the physico-mechanical characteristics of rock masses within the geological

structure of the terrain are suitable for designing hydro energy facilities. In addition, the lime-stone masses are stable and adequately waterproof. However, there is a possibility of the existence of less favourable local zones, but this, after a detailed research, can be overcome by means of design and construction. In the process of constructing SHPs, forest complexes must be protected, even enriched following specially designed programmes, and not endangered and devastated, as is the situation today.

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