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Original Research Paper

Estimation of Vegetation Energy Potential in Natural Ecosystems of Iran

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ABSTRACT

Because of its wide area and geographical diversity, Iran has a nature with different types of vegetation species. Located in desert belt, on one hand, and facing with serious ecosystem threats such as draught, soil erosion, decreased vegetation of desert areas, and overuse of vegetation in the vulnerable areas, on the other hand, has led to the ever increasing attention to Iran ecosystems. In this paper, it is tried to have a suitable estimation about the vegetation energy potential of Iran. Considering the scarce vegetation of Iran, expansion of this vegetation might be a considerable contribution to increasing this potential, which consequently results in the improvement in environmental advantages, such as reduction of soil erosion, increase of herbal fertilizers, fodder for stocks feeding, and oxygen, lowering the shifting sands, and the decrease of dunes and microspores. In this regard, various ecosystems of Iran were selected and their total potential was estimated for one energy unit, considering biomass content in every hectare of land. Moreover, considering the Iran's potential in the production of energy products, vegetation expansion by planting the *Jatropha* was studied in this work in three scenarios. The results of this study indicate that Iranian ecosystems have an annual 2,695,757 billion calories which equals to 1.8 billion barrels of crude oil. Moreover, the results of these scenarios evince that a 5% increase in energy generating vegetation such as *Jatropha* in the desert areas, it is possible to provide 18% of domestic gasoil demand. Hence, it is required to have a support upon creation of energizer vegetation products, as well as supervision of state organizations for creation of a suitable vegetation cover in the entire country.

INTRODUCTION

Iran, with an area of 1.75 million hectares, is a broad land located between 25° and 39° N latitudes (FAO 2008). Except its areas around the coasts of Caspian Sea, Iran is entirely classified among the arid and semi-arid areas of the world.

Iran is bordered by Armenia, Azerbaijan, the Caspian Sea and Turkmenistan to the north, Afghanistan and Pakistan to the east, the Gulf of Oman, the Strait of Hormuz and the Persian Gulf to the south, and Iraq and Turkey to the west. About 52 percent of the country consists of mountains and deserts and some 16 percent of the country has an elevation of more than 2000 m above sea level. The largest mountain massif is that of the Zagros, which runs from the northwest of the country, southwards first to the shores of the Persian Gulf and then continues eastwards till the most south-eastern province (FAO 2008). However, Iran has a warm and wet climate in the coastal areas of the Persian Gulf and Oman Sea. The minimum and maximum temperature in Iran is 20°C and 55°C respectively, while the annual rainfall rate is 228mm (FAO 2008). The presence of these factors has created different climates and ecosystems and, as a result, various vegetation in Iran. The presence of a diverse ecosystem in this arid country has recently introduced serious problems to it. The recent ecosystem threats of Iran, including drought, soil erosion, and water shortage is a problem which should be dealt with by some planning. Unfortunately, there is no comprehensive program for reducing the effects of these phenomena. By having an exact comprehensive plan not only it is possible to control the ecosystems by special organizations and even the people, it is also possible to be benefited from other advantages such as biofuels. The various advantages of natural ecosystems such as prevention of soil erosion and control of air pollutants highlight the importance of vegetative cover, particularly bioenergy plants (Aylott & McDermott 2012). By increasing this cover, indeed, it is possible to be benefited from their ecological and even economic advantages, as it generates job opportunity and biofuels. Therefore, an estimation of the total natural resources of Iran is important for dealing with its recent ecosystem problems. Since the total potential of natural ecosystems in Iran has not been estimated yet, the main purpose of this work is to calculate this potential to improve the quality and quantity of it for the future planning and programs, considering its ecosystem threats.

MATERIALS AND METHODS

To estimate potentials of Iran's ecosystems, first a brief introduction is given about different ecosystems of Iran and their statistics.

Rangeland: Rangeland is a natural ecosystem with grassy, pasturage, and wild plants which is congenitally considered as pasture considering its grazing history. Today, they have a great importance because of their role in fodder supply of the stocks, pharmaceutical and industrial uses, prevention of global warming, carbon stabilization, preservation and creation of a more sustainable life for living organisms and humans. Rangeland is generally defined as, "areas which are not suitable for farming due to the physical limitations, rainfall shortage, topography, rough areas, inefficient drainage, and cold climate. Rangelands are a source of fodder for grazing of the domestic stocks, domestic animals, as well as products of wood industry, water supply and wildlife" (Yamamoto 2001). Rangelands have the major share of earth surface as there are about 2 billion hectares of rangeland in the world (FAO 2012). Thus, soil erosion is decreased if a suitable vegetable cover exists in the rangelands. Table 1 presents rangeland distribution of Iran. According to the statistics, rangelands compose 85 million hectares of the total area of Iran, from which 8.5% are for dense rangelands, 25.2% are for semi-dense rangelands, and 66.3% are for scarce rangelands. Therefore, the main part of Iran's rangelands consists of scarce rangelands (Forests Range & Watershed Management Organization of Iran 2012).

Forests: Forest is the most important carbon storage resources in the earth's ecosystem. The forest ecosystems are based on diversity. Ecosystems are increasingly threatened by the deforestation, climatic changes, and other destructive factors related to human activities. The total area of world's forests is 4 billion hectares which shares 29% of the entire lands of the earth. Two third of forests are in the northern hemisphere, and the rest one third are placed in the southern hemisphere. Moreover, about one third of the world's forests is covered by conifers, and the rest is by broad-leaf plants (FAO 2012). Furthermore, forests have properties such as carbon storage source, creation of the habitat for living species, prevention of soil erosion and desertification, supplying many goods and vital services (wood, firewood, and raw materials for natives, etc.), continuing the food cycle of the life, oxygen generation, water preservation and regulation of hydraulic flows. In general forest is defined as "a land which is mainly covered with bushes and wild grassy plants with an area more than half hectare and tree cover crown naturally more than 5%" (FAO 2012). In managerial view, Iran's forests are classified into two groups as north forests and outside-north forests. Table 2 shows the distribution of Iran's forest which share 8.8% area of the country. The forest area of Iran, without and with prairies and small trees, is 14,319,063 and 16,983,939 hectare, respectively. The biomass content in the north and outside-north forests of Iran is estimated 200m^3 and 50m^3, respectively. In the present research, to estimate biomass content of the forests, the minimum volume of wood in every hectare was used (Forests Range & Watershed Management Organization of Iran 2012).

Deserts: Iran is a country with a 1.2% area the entire lands of the world, where 61% of its area has an arid and semi-arid climate. In total, Iran has 2.4% of desert features lacking any vegetation and shares 3.08% of the world's deserts. Besides, 43.7 million hectares of Iran is located in desert ecosystem, where 32 million hectares of this area is the desert features lacking any vegetation and does not enjoy the moderate climate due to its low rainfall. The area of deserts in Iran is given in Table 3. The arid and semi-arid areas amount to 6.1 billion hectare which is 47.2% of the earth surface. Almost, 1 billion hectare of this area is covered with arid deserts with insignificant biological products. The rest 5.1 billion hectares consist of arid areas and areas with very low humidity (Forests Range & Watershed Management Organization of Iran 2012). According to FAO, "desert is a land in arid, semi-arid, and semi-wet areas which either lack sustainable vegetation or it's vegetation is not suffice to its economic exploitation under natural conditions" (FAO 2008).

In the desert areas typically rainfall is low, the temperature is severe, and evaporation is very high. In these areas, evaporation is almost twice the rainfall and wind is the main erosion factor. The vegetation is very scarce in these places. Deserts are typically located between north and south 15 to 302 latitudes and have a dry climate. The rainfall has its minimum rate in deserts and soil is very poor. Soil erosion and human activities lead to aggravation of desertification phenomenon, which threatens 1/6 of population, 3/4 of the arid lands, and 1/3 of world lands with an area of 5 billion hectares in 110 countries. The areas affected by wind erosion of the world amounts to about 232 million hectare. The areas affected by wind and water erosion are respectively 20 and 75 million hectares in Iran (Forests Range & Watershed Management Organization of Iran 2012). The biomass content in each hectare of the desert is very low, so that the erosion is intense in these areas. To estimate the potential of the natural ecosystems of Iran, three types of ecosystem, including rangelands, forests, and deserts were considered. Then, based on their area, the biomass content was estimated for them. Iran's forests have a variable amount of biomass content. Table 4 presents computations of biomass content for north and outside-north forests of Iran.

To compute biomass content, first biomass content of forest foods was measured in cubic meter. To do so, in Table 4, column 1 is multiplied by column 2 and biomass content of the forest woods (column 3) is obtained. Since the estimation of biomass content is required for our computa-

tions, this biomass content of wood must be converted to biomass content. For each ton of wood has a volume of 1.4m^3 (Boundy et al. 2010), column 3 is divided into 1.4 and the entire biomass content of the forest is obtained. Based on these computations, the biomass content of north and outside-north forests of Iran were estimated as 281 and 441 million ton, respectively.

To compute the biomass content of the natural ecosystems of Iran, as given in Table 5, first their biomass contents are estimated (row 1) and are divided into their corresponding area (row 2). Row 3 of Table 5 presents biomass content of one hectare of each ecosystem.

According to the computation of this work, each hectare of north and outside-north forests of Iran, rangeland, and desert in Iran contains 143,000, 36,000, 250, and 50 kg biomass, respectively. The maximum biomass content is for north forests, since they contain dense and semi-dense forests. On the other hand, desert indicates minimum biomass content due to its lack of adequate vegetation.

RESULTS

Since the Iran's ecosystems are faced with critical conditions due to the serious ecosystem threats such as drought, soil erosion, and excessive grazing of the rangelands, it is necessary to consider development of vegetation in arid lands for reducing desertification rate as the top priority in the future multi-purpose plans for creation of a sustainable development. Hence, estimation of vegetation potential for future planning is of great importance. To estimate biomass content in energy units, it is required to convert the vegetation area to wood charcoal. Over the past 50 years, charcoal production in Iran has decreased from 500 ton in year (Mojtahedi 1955) to the annual amount of 57 ton in north forests (Anonymous 1985). In general, the thermal value of various vegetation covers is different, due to the difference in the wood type. The energy generated by the hard wide-leaf trees is difficultly and slowly released, but it is larger and lasts longer. On the contrary, the wood of conifers is quickly released and produces higher combustion heat. Table 6 illustrates the thermal energy of different solid fuels. As thermal energy varies in different plants, estimation of the energy for the entire plants of Iran and computation of their thermal energy is not possible. Therefore, it would be better to consider the minimum thermal value of woods (column 6) for computation of the overall thermal potential of Iran, i.e., 3600 Kcal. In this paper, to estimate the potential of natural ecosystems, it is assumed that every 1 kg of biomass from rangeland, forest, and desert has the same thermal energy content of 3600 kcal. Table 7 presents the entire biomass computed for Iran, which is 748 billion kilograms. As each kilogram of biomass produces 3600 kcal of energy, the thermal value capacity of the entire biomass in Iran is computed as 2,695,757 billion kcal. Finally, this value is converted to the energy unit equivalent of each crude oil barrel. Since each barrel of crude oil contains 683.8 × 10-9 kcal (Administer of Energy, Office of Energy Planning, 2012), the thermal value of these ecosystems is estimated as 1.8 billion of crude oil.

Due to the expansion of desertification and ruin of existing ecosystems in the country, the reduced vegetation will not be improbable in the future. Increasing the vegetation level of Iran must be highlighted, considering the potential of its ecosystems. Planting energy-generating plants in small areas of deserts not only creates occupation, but also reduces desertification and enhances the potentials of natural ecosystems. To determine the energy content by increasing vegetation content, in this research, using *Jatropha* plant, was studied in the arid areas of Iran, which amounts to 32 million hectares. In this regard, three scenarios, including minimum, medium, and maximum vegetations were considered. It is worth to mention that each hectare of *Jatropha* generates 3.5 ton of biodiesel. Table 8 illustrates these three scenarios. Considering its average density of 880 kg/m^3, each ton of biodiesel is 1136 litre. Thus, each hectare of *Jatropha* produces 3976 litre of biodiesel. The energy content produced by the increased area of energy-generation vegetation (*Jatropha* plant in this work), is 6361.6, 12723.2 and 19084.8 million litre of biodiesel for the three scenarios developed in this research.

DISCUSSION AND CONCLUSION

Because of its broad geographical area, Iran has different climates, where this climate diversity results in creation of various ecosystems in it. Considering ecosystem threats of Iran such as draught, water shortage, soil erosion, etc. the plans should be focused in this area. Thus, estimation of the total potential of Iran's ecosystem provides a broader horizon for the grand decisions and plans toward the macro and micro purposes. The main objective of this work is to estimate the energy capacity of Iran's vegetation. Indeed, the measured potential indicates the present status of natural ecosystems of this country, which are abandoned and no considerable attempt is made for their improvement.

The benefits of energy crops include not only their use for biomass heat and electricity, but also their ability to store carbon, benefit industrial landscapes, prevent erosion, improve biodiversity in the right location and ensure fuel security (Aylott & McDermott 2012).

The results indicate that Iran's ecosystems contain 2,695,757 billion kcal of energy which amounts to 1.8 bil-

Table 1: Distribution of Rangeland in Iran in 2011.

Rangeland type	Dense Rangelands (good)	Semi-scarce Rangelands (medium)	Scarce Rangelands (poor)	Total
Area (hectare)	7181250	21419151	56214590	84814991
Percentage (%)	8.47	25.25	66.28	100

Reference: Forests Range & Watershed Management Organization of Iran 2012

Table 2: Distribution of Forests in Iran in 2011.

Forest type	Dense forest	Semi-dense forest forest	Scarce forest forest	Sustainable forest forest	Forest under planting	Total
Area (hectare)	1780290	3468312	8100842	25760	943858	14319063
Percentage (%)	12.4	24.2	56.5	0.2	6.6	100

Reference: Forests Range & Watershed Management Organization of Iran 2012

Table 3: Area of deserts in Iran in 2011.

Desert lands	Salt pans	Sand dunes	Sand zones	Clay zones	Saline lands and outcrops	Uncovered lands	Total
Area (hectare)	5838375	1762136	615042	435803	6558281	17366855	32576492
Percentage (%)	17.9	5.4	1.9	1.4	20.1	53.3	100

Reference: Forests Range & Watershed Management Organization of Iran 2012

Table 4: Biomass content of north and outside-north forests of Iran.

Forest type	Wood volume in each hectare (m^3)	Forest area (hectare)	Biomass content of forest foods (m^3)	Total biomass content of the forest (ton)
North forest	200	1967316	393463200	281045142
Outside-north forest	50	12351747	617587350	441133821

References: research findings

Table 5: Estimation of biomass content in each hectare of Iran's ecosystems.

Biomass content	Rangelands	Type of natural ecosystem Forest (without prairies and bush lands) North forest	Desert Outside-North forest
Total biomass content (ton)	21400000	281045142	441133821
Total area (hectare)	84814991	1967316	12351747
Total biomass content in each hectare (kg)	250	143000	36000 50

Reference: research findings

Table 7: Estimation of biomass in total areas of Iran.

Vegetation type	Rangelands	Forest (without prairies and bush lands) North forest	Outside-North forest	Desert	Total
Biomass content (ton)	250	143000	36000	50	-
Area (hectare)	84814991	1967316	12351747	32576492	-
Total biomass (kg)	21203747750	281326188000	344662892000	1628824600	748821652400

Reference: Research findings

Table 6: Thermal value of different solid fuels (kcal/kg).

Fuel type	Thermal value
Anthracite	7800
Coal	7500
Bitumen coal	7343
Typical charcoal	7000
Coke	6500
Completely dry typical woods	3600-5396
Haloxylon persicum	7343
Prosopis juliflora	7800
Eucalyptus camaldulensis	4800
Acacia nilotica	4950
Prosopis cineraria	5000

Reference: Panshin et al. (1962), Anonymous 1981

Table 8: Scenarios of increasing vegetation cover in desert areas.

Vegetation increase scenarios (%)	5	10	15
Vegetated area (million hectare)	1.6	3.2	4.8
Generated biodiesel (million litre)	6664	13328	1992
Share of domestic gasoil use (%)	0.18	0.36	0.54

lion of crude oil barrel. Despite such high potential of these ecosystems, they are abandoned and if this trend proceeds, they would be destroyed even more in the future. However, the attention of the authorities to this concern and moving towards conservation and restore of natural ecosystems, would be a big step to dealing with the ever-increasing present environmental concerns. As a large area of Iran is covered with scarce rangelands and deserts, by planting in these areas, it is possible to be benefited from the mentioned advantages, as well as enhance the potential of natural ecosystems. The biomass content of Iran is estimated as 21 million tons, where 50% of it is the allowable harvestable grass. Therefore, the extractable biomass of the rangelands is 125 kg per hectare. About half of Iran's rangelands lack vegetation or are scarce. By planting suitable plants in these areas, it is possible to increase vegetation of the rangelands and, consequently, their energy potential. Doing so, would result in the better grazing of stocks in the rangelands and a considerable save in the national economy for fodder supply. Moreover, since only 10% of the country is covered with forests, using the vegetation in forests for personal use and interest is not recommended. The presence of abundant forests guarantees public health and sustainable development. However, it is required to propose appropriate strategies for the complete preservation of physical advantages of the forests can damage the national economy.

One strategy for this problem is to oblige people who cut a tree to plant several trees in its place. Since the environmental costs imposed by cutting one old tree are high and even irreparable, the number of planted trees instead of the cut one must be considerably higher. Moreover, it is required to assign some fines for those who destroy the environment. Although the transgressors would follow their interests, the sustainable development trend would be maintained in this way and the future generations would tolerate less damage. Moreover, presence of regulatory bodies who directly supervise in the forest areas and suitable policies for forest conservation are among the effective measures. Although there are some organizations who supervise forests and other natural ecosystems, the organizations which are determined for improvement and development of vegetation in reaching goals such as natural ecosystem improvement and conservation have not been successful. Therefore, the presence of these regulatory bodies is a necessity in these areas. Furthermore, 20% of Iran is covered with deserts with scarce vegetation, and there is no potential of using the vegetation to estimate virtual potential of harvest in it. Despite this scarce vegetation, some residents of these desert areas damage its vegetation and impose some costs to the national economy. Thus, the authorities are required to provide needs of these people to prevent the falling vegetation of this ecosystem. If these people, whose lives depends on their surrounding deserts, are not supported, the vegetation content of this ecosystem is decreased since they need to meet their needs. But offering proper support for improving their economic status and even passing some rules for fining the vegetation damage would definitely result in a better condition. As a matter of fact, by offering proper support to the residents of desert areas, soil erosion in this ecosystem, which annually imposes higher costs to the national economy, would be prevented. A suggestion for these areas can be allocation of desert lands and selling seeds of energy-generating plants with low prices to these residents. The seeds of plants which are able to grow in desert areas and are resistant to aridity and salinity such as Salicorina plants and *Jatropha* would be good options. To estimate energy content of *Jatropha* vegetation in arid areas, three scenarios were considered in this work. As each hectare of desert can yield 3.5 tons of *Jatropha* and each ton of biodiesel (considering its 880 kg/m^3 density) generates 1,136 litre of biodiesel, each hectare of *Jatropha* can generate 3,976 litre of biodiesel. Based on these three scenarios, the energy content generated by the increase in *Jatropha* vegetation was 6361.6, 12723.2, and 19084.8 million litre of biodiesel, which is equal to the minimum 0.18% and maximum 0.54% of domestic gasoil use of Iran in 2012 which was 35245.9 million litres.

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