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Challenges and Environmental Impacts of Biomass Energy in South Asia

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SM and AD designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Author SB managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Plants utilise solar energy to synthesise food during photosynthesis as it provides biomaterials needed for generation of bio-energy. A byproduct of natural and biological sources can be used as a source of bioenergetics; it is a good replacement for carbon energy or fossil fuel. In this article, a variety of biomasses, its impacts on the environment and challenges in production are discussed coherently. This study focuses on the advantages and disadvantages of Biomass-derived fuels and its utilisation in Asia. Production of Sugarcane, Palm oil and Sorghum is compared among all Asian countries. Current research on palm oil effluents revealed that oil palm was a more energy friendly crop and oil palm cultivation under current practices posed no risk to the environment. Comparative reports on consumption of fuels and Biomass trade have been discussed Introduction of four fuel and fifth fuel strategy ensure reliability and security of energy supply which includes petroleum, natural gas, hydropower and coal to reduce consumption of petroleum. In Malaysia, Petroleum dependence has been drastically reduced from 98% in 1980 to 8% in 1999. Recently, fifth fuel

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renewable energy is introduced by government which provide an alternative to the other sources of energy. Biomass fuels are a sustainable, efficient and viable source of energy. It can be generated from a waste material which also provides an efficient way of waste management. Countries with high agricultural resources can look forward to biomass energy production. In the coming years, biomass energy will be a small but significant part of the energy. This may be beneficial in increasing the economy of a country. Biomass energy can be achieved with a high success rate with the help of advanced technology, effective government policies, and international trade.

Keywords: Biomass; solar energy; biomaterials; natural resources; photosynthesis; fossil fuel; bio-fuels; bio-energy; waste management; trade.

1. INTRODUCTION

Our environment includes all the necessary components for the survivability of life. Natural resources such as air, water, soil, minerals and climate make up the surrounding of living organisms; they are further classified into four basic components of the environment, viz, Atmosphere, lithosphere, hydrosphere, Biosphere. These four spheres are connected with each other by biogeochemical cycles that make energy transfer. Sun is the primary source of energy for all types of ecosystems (forest grasslands and aquatic). Biogeochemical cycles transfer energy from one tropic level to another in the food chain. The ecological pyramid shows that an energy pyramid is always upright.

Gross Primary Productivity (GPP) is referred to total energy captured by the photosynthetic organism. Mean net primary production is high in tropical rain forest while it is the lowest in deserts. Net Primary Productivity (NPP) is the net stored energy in the green plants. This is the net accumulation of biomass which serves as food for herbivores and decomposers.

$$NPP = GPP - Respiration \quad (1)$$

NPP is referred as a measure of amount of organic matter produced in a community in a given time available to the heterotrophs. Aquatic ecosystems in Silver Springs, Florida, the net productivities (rates of energy storage as biomass) for trophic levels were [1]:

Primary producers (plants and algae): 7618 kcal/m^2/yr.
Primary consumers (snails and insect larvae): 1103 kcal/m^2/yr.
Secondary consumers (fish and large insects): 111 kcal/m^2/yr.
Tertiary consumers (large fish and snakes): 5 kcal/m^2/yr.

Transfer efficiency varies between levels and do not show precise value of 10%.

$$\text{Transfer Efficiency} = (\text{Primary consumer}/\text{Primary producers}) \times 100 \quad (2)$$

Secondary productivity is referred to as the net rate of increase in biomass of heterotrophs at the consumer level. This turns as food to the next trophic level. There are three types of radiation emitted by sun (1) UV radiation; 30% of total (2) Infra-red radiation; 20% of total (3) Visible light or photo synthetically active radiation (PAR); 50% of total [2].

Fifty (50%) of total radiation is visible light, only 2 – 10% (PAR) of this is used in photosynthesis.

Some natural and biological sources are appropriate for producing renewable energy which is classified as bio-energy. Byproducts of different ordinary sources such as plants, animals, waste materials can be utilised in the production of bio-energy as a major part. Modern technology like an abandon coal mine, dumping ground, pits created by mining, landfills or waste zones, even makes potential bio-energy resources. These areas are suitable for the collection of biomass and heat, fuel, and gas can be produced from such lands which are also sustainable power sources.

2. BIO-ENERGY

Plants produce chemical energy with the help of chlorophyll in the presence of sunlight during photosynthesis which can be replenished and considered as an unlimited source. The greatest source of carbohydrate biomass is photosynthesis as it provides biomaterials used for bio-energy generation.

Bio-energy can be a good replacement for carbon energy. There are many sources of bio-energy, but the most common are forests,

agricultural farms, and waste. These contribute in large quantity and can be used again. For the source of energy, farmers cultivate sugar and starch-rich crops which provide sufficient amount of biomass energy that may be utilized for agricultural purposes. These crops include sugarcane and corn which are a good source of starch and sugar [3].

2.1 Bio-Energy as an Alternative Resource

Bio-energy is a good alternative for fossil-based fuel. Fossil-based fuel mainly consists of hydrocarbon which is highly toxic. Bio-energy has the potential to decrease carbon marks (statistical analysis method for determining the amount of carbon present in the atmosphere) and improve the environment. The amount of carbon utilised by bio-energy and fossil fuel is more or less the same, but the harmful impacts of bio-energy based fuels are less than fossils fuels [4]. Petrol and diesel are extensively used as transportation fuels that may be replaced by bio-energy based fuels. Use of woods for generating energy is also decreasing as the use of bio-energy is becoming prominent and effective in urban as well as rural areas. Different developed countries are accepting this trend which is providing a fundamental basis of the scale of economic growth to the development of domestic industries. Despite its use as a traditional biomass dominant domestic fuel, especially in more rural areas, it is still recessive in developing countries and more popular in developed countries. Figure describes the estimated trade of biomass. There are multiple challenges and

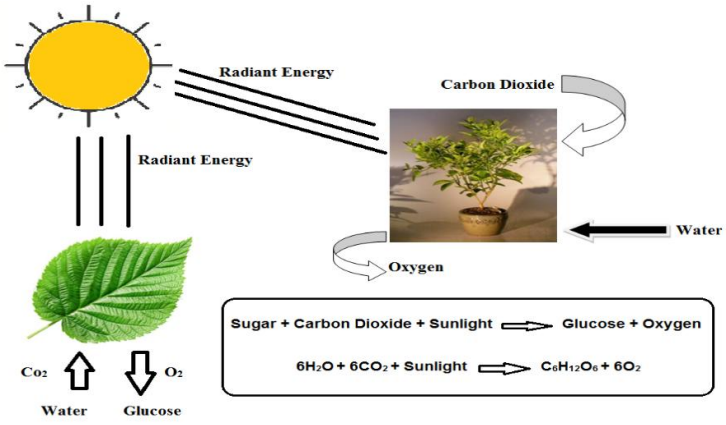


Fig. 1. Picture representation of the photosynthesis process

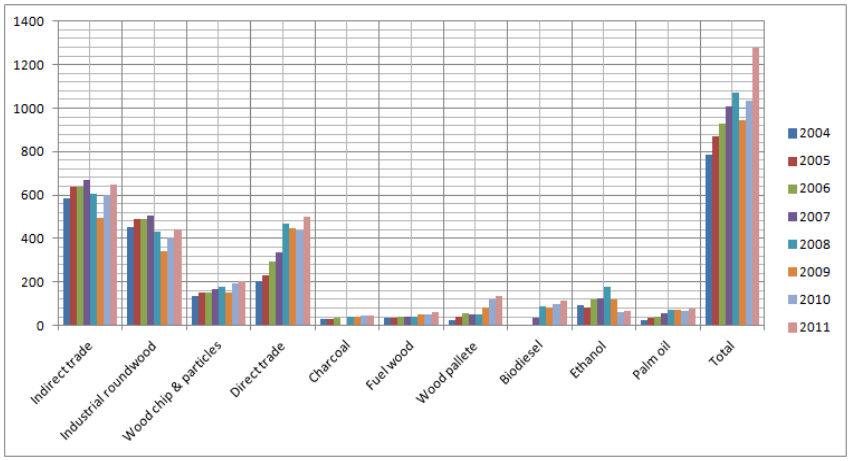


Fig. 2. Estimated international biomass trade in 2004-2011

opportunities which affect the sustainable development of bio-energy as a potential driver, given enough economic and technological support [5].

2.2 Classification and Source of Bio-energy

Collection of different resources constitutes the source of bio-energy and its usage varies from continent to continent and from country to country. However, the bio-energy is considered as a worldwide power in current time because of its increased use in the trade of biomass for transport.

Biomass can mainly be supplied through three different sources.

(1) Agriculture; (2) forestry; and (3) waste materials. Most of the countries utilise resources from these sources to develop a sector for modern bio-energy producing plants.

3. BIOMASS

Any organic matter like woods, crops etc. that is utilized as an alternate form of energy is known as biomass energy. It is also a renewable form of an energy source as its supplies are not limited. It is considered one of the ancient sources of energy after the sun. For years, people use wood as a fuel to prepare their food and warm their homes. Biomass gets its energy from the sun. All organic matters contain stored energy from the sun. During the photosynthesis process, sunlight energy is absorbed as photons by plants which are used to produce oxygen and sugar by converting Co_2 and water. Foods rich in carbohydrates are a good source of energy for the human body.

Productivity Equation [6]

$$P = \frac{(Xmax - In(Xi)}{t} \quad (3)$$

Where, P = productivity, Xi = initial biomass concentration, Xmax = maximum biomass concentration, t = cultivation time related to the maximum biomass concentration (d)

Growth Measurement [6]

$$\mu = \frac{(In(\mu m) - In(Xi)}{t} \quad (4)$$

Where, Xi = initial biomass concentration, Xm = maximum biomass concentration, t = cultivation time between Xi and Xm (d).

3.1 Types of Biomass

Biomass includes all the types of plants and animals but major part of biomass is unused. Only usable types of biomass are discussed here.

3.1.1 Wood & agricultural products

This includes wood—sawdust, logs, chips, and barks —accounts for the maximum percent of biomass energy. The waste products from agricultural fields are used to produce electricity. These are wood, wood waste, pits, and corncobs. Electricity in paper mills is produced by the waste products generated during the processing.

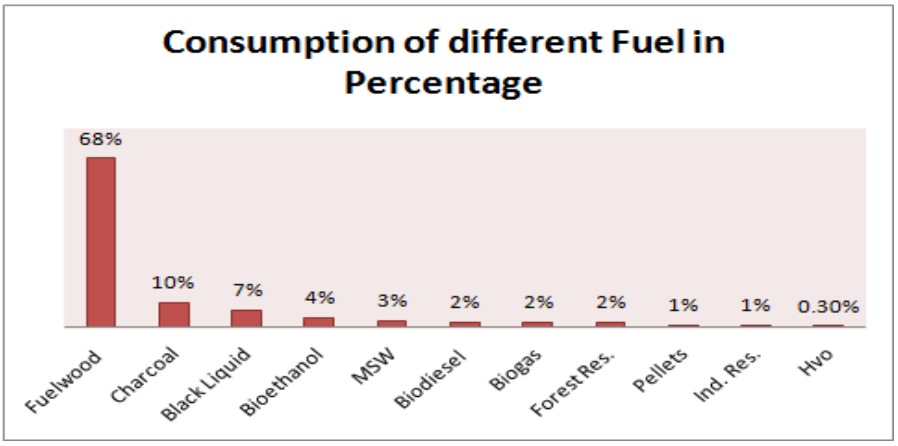


Fig. 3. Consumption of different fuels in percentage (%)

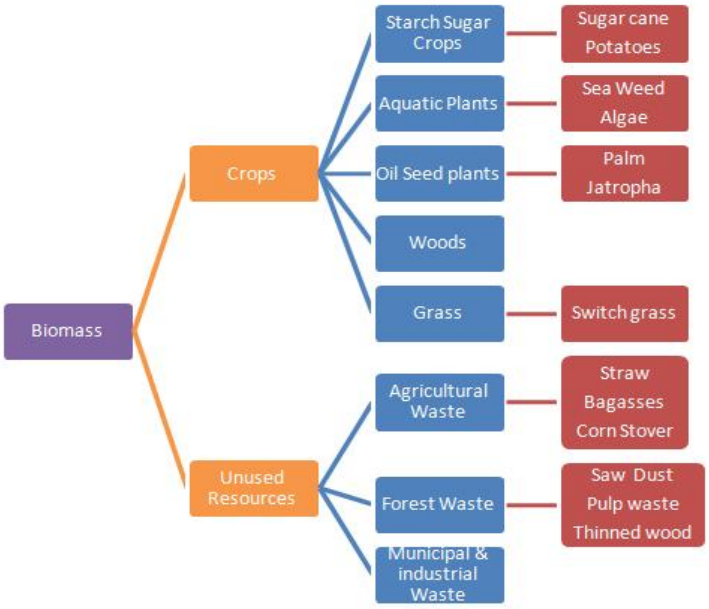


Fig. 4. Hierarchy of biomass feedstock

3.1.2 Solid waste

Solid waste is blistered to produce waste which is used to produce energy. Not all biomasses are garbage: as a maximum of its energy comes from waste produced from natural gas and petroleum. Waste energy plants are power plants which produce energy by burning the waste materials. These industrial plants produce electricity equally as coal plants, but the combustion rate of waste energy plants is lower as compared to a coal plant.

3.1.3 Landfill gas & biogas

Some microorganism like bacteria and fungi depends on dead and decaying matter. They eat dead animals and plants, causing them to rot or decay. Microorganisms depend for their food on sugar which is produced from alteration of cellulose. Even though the process in a landfill is slowed, it promotes methane gas production as the waste product which is used as biogas in house. Methane is odourless, colourless and harmful gas, highly inflammable which may cause an explosion. This gas is collected in a landfill, purified and used as fuel. Human and agriculture wastes are being used to synthesize methane gas. The biogas plant is an airtight pit or containers creased with bricks or steel [7]. Bio-gas containers collect waste which is fermented in anaerobic condition to produce gases rich in methane. This gas has several advantages and can be utilised for cooking and to produce electricity.

3.1.4 Ethanol: Sugar cane [8]

Ethanol is an ethyl alcohol fuel derivative which is produced by fermenting starch and sugars, found plants. It can be produced from organic materials containing starch, sugar, and cellulose. One of the major sources for ethanol production is corn. With innovative technologies, ethanol is produced from cellulose, a fiber founds in grasses, trees, and crop residues. Normal fuel like diesel is blended with ethanol to increase its efficiency. Fuel mixed with 15% gasoline and 85% ethanol, qualifies as an alternative fuel.

3.1.5 Biodiesel

Biodiesel is manufactured by reaction of an alcohol with animal fat, vegetable oil, and grease chemically. Most of the biodiesel used today are made up of soybean oil. It is often mixed with petrol and diesel in a ratio of 2:5:20. [9] It can also be used in its purest form. Sulfur content is almost zero in biodiesel; therefore, its use alternative fuel for vehicles would be helpful in reducing sulfur levels in the environment.

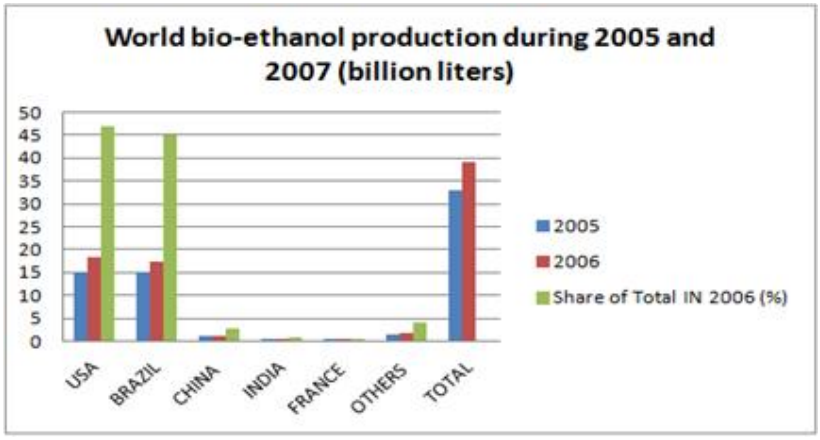
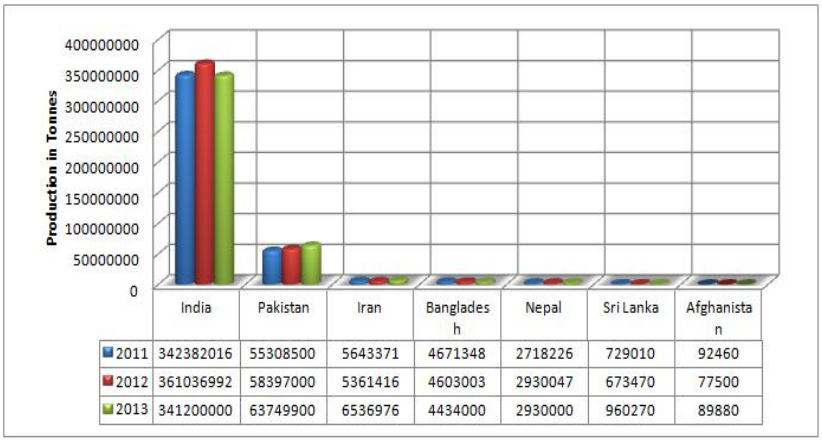


Fig. 5. World bio-ethanol production during 2005 and 2007 (billion litres) [10,11]



	India	Pakistan	Iran	Bangladesh	Nepal	Sri Lanka	Afghanistan
2011	342382016	55308500	5643371	4671348	2718226	729010	92460
2012	361036992	58397000	5361416	4603003	2930047	673470	77500
2013	341200000	63749900	6536976	4434000	2930000	960270	89880

Fig. 6. Production of sugar cane in Asian countries based on Food and Agriculture Organization (FAOSTAT data source) [12]

3.2 Biomass in Asia

Biomass is becoming an essential source of energy in the south-east part of Asia. Though biomass is a popular source for energy still the use of woods for fuel dominates in 50 percent of the continent. By country, the primary biomass energy supply share in the year 1999 was: Myanmar 86%; Lao PDR - 86%; Cambodia - 83%; Vietnam - 48%; Indonesia - 29%; Philippines - 21%; Thailand - 17%; and Malaysia - 8% [13]. Biomass energy is largely utilised in small-scale industries and in the household sector. Recently, biomass is used in combination with heat and power generation. The role of biomass is limited in power development, but there are opportunities such as small energy production, intensive labor, cheap raw materials that can increase its share [14].

Henson [15] and Anderson [16] studied on palm oil effluents and concluded that oil palm cultivation under current practices posed no risk to the environment. Fresh and dry weight of empty fruit bunch, shell, fiber and effluent have been analysed in tons per hectare per year after milling from 1 ha of mature palm.

A quantity estimate was provided by Chua [17] for Biomass generated by palm oil mills in 1997 Biomass Quantity (million tons) based on estimate of 148 palms/ha. On the basis of that estimate POME I.e palm oil mill effluent were analysed by S. Yusoff [18] and Wood and Corley [19]. They have concluded that "*oil palm was a more energy friendly crop than others".*

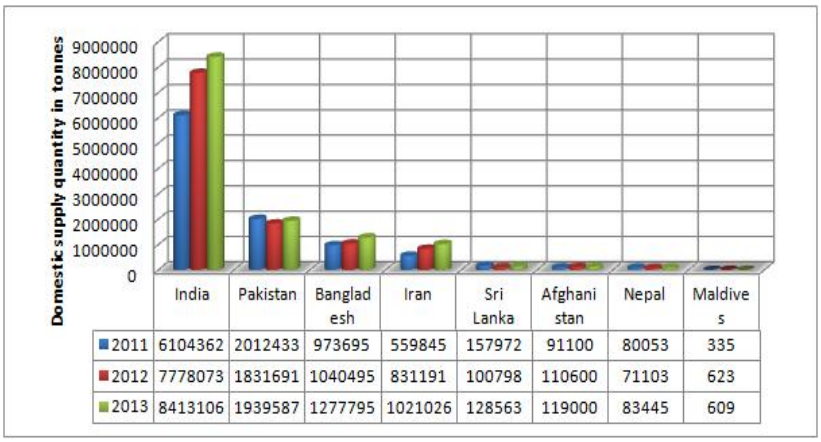
However, the world production of liquid fossil fuel (petroleum and natural gas) has been declined during this decade [20]. Greenhouse gases

significantly impact on global climate change due to increased consumption of energy. Scientific assessment based on the available instrumental observational records from the industrial era to the present day, scientific assessment shows that mean sea level has risen between 10 and 25 cm and global mean temperature has been increased by between 0.3 and 0.6 C since the 19th Century. Renewable energy technologies are eco-friendly and leads towards sustainable development.

Production of sugarcane, palm oil and Sorghum is highest in India followed by Pakistan among all Asian countries.

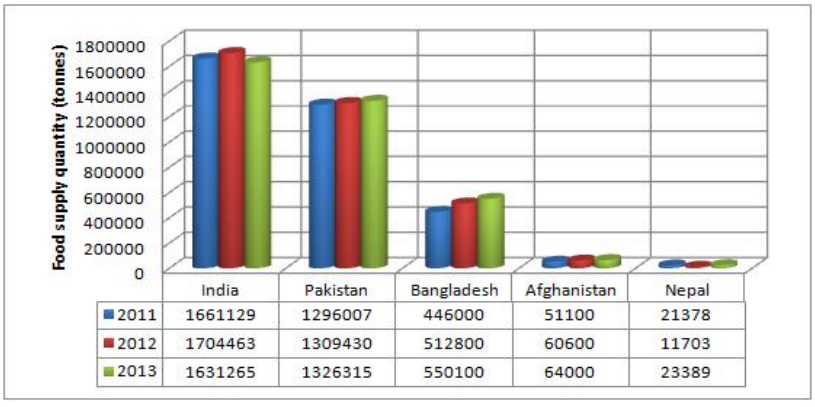
As the population in India is increasing, its energy demand is also increasing. (Ravindranath and Balachandra, 2009). Energy consumption in India has increased up to 42.1% per capita. As the country has a large agriculture land, availability of biomass is high; therefore, burning this biomass is the easiest and oldest method to generate energy [21]. Over 70% of the population of India lives in villages but these villages neither get sufficient electricity nor water supply [21]. These supplies are essential for the lives of humans; therefore, methods should be developed to fulfill these demands. Therefore, biomass found in the villages must be utilised to fulfill the demands. Gasification of biomass offers large scope for electricity production and water pumping in India.

Four-fuel strategy fifth fuel strategy: Malaysian government introduced the new strategy that is four-fuel strategy which include petroleum, natural gas, hydropower and coal to reduce



	India	Pakistan	Bangladesh	Iran	Sri Lanka	Afghanistan	Nepal	Maldives
2011	6104362	2012433	973695	559845	157972	91100	80053	335
2012	7778073	1831691	1040495	831191	100798	110600	71103	623
2013	8413106	1939587	1277795	1021026	128563	119000	83445	609

Fig. 7. Domestic supply quantity of palm oil based on Food and Agriculture Organization (FAOSTAT data source) [12]



	India	Pakistan	Bangladesh	Afghanistan	Nepal
2011	1661129	1296007	446000	51100	21378
2012	1704463	1309430	512800	60600	11703
2013	1631265	1326315	550100	64000	23389

Fig. 8. Food supply of palm oil in Asian countries based on Food and Agriculture Organization (FAOSTAT data source) [12]

consumption of petroleum in order to stimulate economic growth by ensuring reliability and security of energy supply. In Malaysia, Petroleum dependence has been drastically reduced from 98% in 1980 to 8% in 1999. Recently, renewable energy as the fifth fuel is introduced by government which makes renewable energy popular and an alternative to the other sources of energy.

4. ENVIRONMENTAL IMPACT AND CHALLENGES OF BIOMASS ENERGY PRODUCTION

In the environment, biomass has more advantages than fossil fuels such as petroleum and coal. It contains less nitrogen and sulfur than fossil fuel; therefore, it does not cause acid rain. Growing plants for use as biomass fuels may also help to keep carbon dioxide levels balanced. Plants help in the removal of Co_2 from the atmosphere when they grow using photosynthetic reaction.

There are many challenges in the production technology of biomass energy. The most critical challenge for the biomass industry is food security [22]. Biofuels is accountable for a rapid price increase of grains for decades in the international markets [23]. Grains were exported to the production plants from the market for the biofuel production [24]. Eventually, the high price of food decreased the supply of food resulted in serious productivity, health conditions [25]. The cellulosic biomass technique allows entrepreneurs to have an extensive diversity of crops for biomass production. Several cropping techniques such as step farming, cellulose-rich farming are being developed by scientists to produce biomass, including perennial and annual species of plants species [26]. Due to the comprehensive carbon cycle, these cropping methods help in the reduction of soil erosion and nitrogen loss. The only barrier for these cropping technologies is a limited conventional market [Villamil et al. [27] advocated that environmental campaigns should be organised to increase awareness and education on energy crops. In addition, harvesting cellulosic biomass requires removal of plant residues [28]. Agricultural scientist and Farmer are concerned about how the simultaneous harvest of grain and stover will affect grain productivity, soil quality, and long-term sustainability [29,30]. Furthermore, the storage and transportation of cellulosic biomass are different from grains [31]. Biomass quality is also examined by its ash content and gross energy [32]. There is a lack of literature or research articles about developmental plans of cellulose biomass market [26].

During last few years, environmental issues have become more important in Malaysia and all over world. The environmental pollution is a familiar issue in palm oil industry and it is struggling for quality and suitable environmental conservation towards 'sustainable development and cleaner technology'. The oil palm industry must be equipped to face new challenges onwards. Highly organized developmental approaches with technical protocols are needed for rapid growth which must implement know- how technical detail for oil palm industry. Environmental laws and regulations and Environmental Quality Act (EQA) [33] have been implemented to govern crude palm oil mills and facilitated problem of environmental pollution in the Malaysia which must be addressed on by the enforcement of environmental regulations. Although controlling measures in CPO mill are working to control air pollution but these are not sufficient for complete amenability of regulatory requirements. New technology for effluent discharge, Boiler design technology, solid fuel treatment and combustion, fly ash control system, and energy conservation concept should be focus of study in relation to complete combustion Rosanani Ibrahim, 1999 [34]. Duet to Constant deterioration of inland water quality may affect water quality which might requires to maintain strict water quality standards in the future. Thus, new and improved treatment technology would be required in order to meet the new requirements. A river basin environmental management might regulate sets of stricter effluent discharge standards than earlier. Palm oil industries have been using Self-regulated environmental management tools like the ISO 14000 EMS and life cycle assessment (LCA) for systematic assessment of whole operation and pollution prevention strategies [35]. The self-regulation certainly plays an important role and contribute to current environmental management system [17].

Meyer [32] indicated increased biomass production can lead to noticeable consequences on water consumption. Quality of water is also affected by agricultural drainage containing pesticides and fertilizer sediments. Cultivation of low -water-consuming crops can be an alternative in drought-affected area [36]. There are many critical conversations among researcher, educators, and entrepreneur on "how to make biomass energy production more environment-friendly" [38].

5. ADVANTAGES AND DISADVANTAGES OF BIOMASS ENERGY

There are some pros and cons of biomass energy which are discussed below [37].

No.	Advantage	Disadvantage
1	Biomass energy is an abundant, secure, environmentally friendly and renewable source of energy.	Biomass is still an expensive source of energy, both in terms of producing biomass and converting it into alcohols, as a very large quantity of biomass is needed.
2	Biomass does not add carbon dioxide to the atmosphere as it absorbs the same amount of carbon in growing as it releases when consumed as a fuel.	On a small scale, there is most likely a net loss of energy as a lot of energy must be used for growing the plant mass; biomass is difficult to store in the raw form.
3	Biomass can be used to generate electricity with the same equipment or in the same power plants that are now burning fossil fuels.	One of the disadvantages of biomass is that direct combustion of biomass can be harmful to the environment as burning biomass releases carbon dioxide, which contributes to the warming of the atmosphere and possible climatic change.
4	Biomass energy is not associated with environmental impacts such as acid rain, mine spoils, open pits, oil spills, radioactive waste disposal or the damming of rivers.	Over-collecting wood can destroy forests. Soils bared of trees erode easily and do not hold rainfall. Increased runoff can cause flooding downstream.
5	Biomass fuels are sustainable. The green plants from which biomass fuels are derived fix carbon dioxide as they grow, so their use does not add to the levels of atmospheric carbon. In addition, using refuse as a fuel avoids polluting landfill disposal.	When plant and animal wastes are used as fuel, they cannot be added to the soil as fertilizer. Soil without fertilizer is depleted of nutrients and produces fewer crops.
6	Alcohols and other fuels produced by biomass are efficient, viable, and relatively clean burning.	Biomass has less energy than a similar volume of fossil fuels

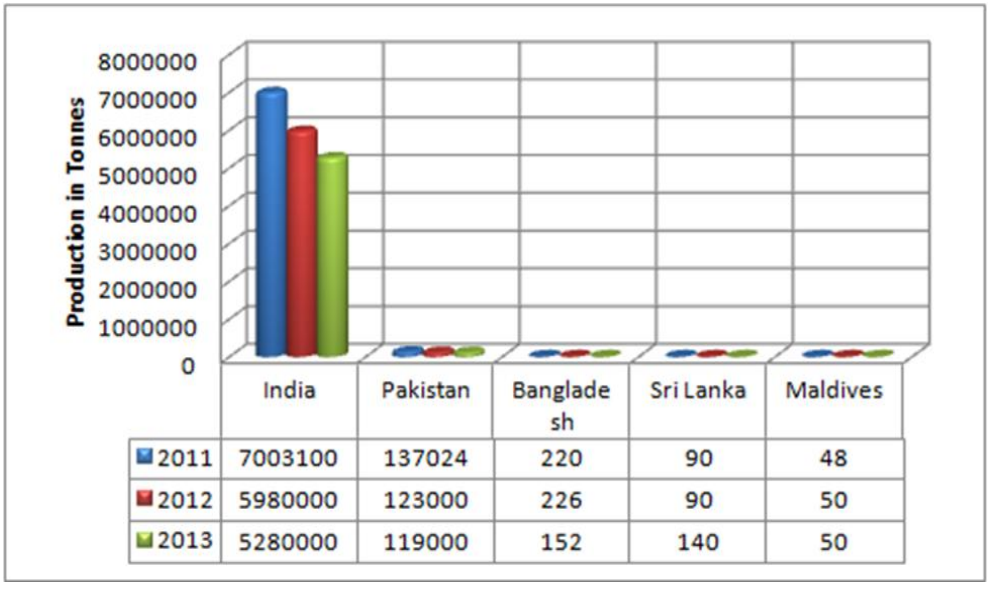


Fig. 9. Food supply of sorghum in Asian countries based on Food and Agriculture Organization (FAOSTAT data source) [12]

6. CONCLUSION

In the coming years, biomass energy will be a small but significant part of Asia's energy. If this technology is well developed and managed, it can be very advantageous for society. This energy can be a good alternative to fossil fuel like coal and petroleum. These fuels are very harmful to the environment which can cause a serious issue. These fuels need to be replaced to save the environment for the future. Biomass energy can be generated from waste materials also; therefore, utilization of waste material can also help in waste management [39]. There are many benefits of biomass energy which can be considered in present to build a better future. Apart from benefits, there are many negative impacts which cannot be ignored. Though these industries provide employment and help economically and socially, there are many environmental issues which are a matter of concern. These problems can be overcome if biofuel production is handled carefully [40]. Deforestation and intensive monoculture can also be a serious issue affecting livelihoods. Watersheds and carbon sinks could be annihilated, and various forms of wildlife could become extinct. Rising food prices could lead to political instability, as well as malnutrition and disease. Production of sugarcane and palm oil is highest in India followed by Pakistan among all Asian countries [41]. Current research on palm oil effluents revealed that "*oil palm was a more energy friendly crop than others and oil palm cultivation under current practices posed no risk to the environment.* Four-fuel strategy include petroleum, natural gas, hydropower and coal to reduce consumption of petroleum in order to ensure reliability and security of energy supply. In Malaysia, Petroleum dependence has been drastically reduced from 98% in 1980 to 8% in 1999. Recently, fifth fuel renewable energy is introduced by government which provides an alternative to the other sources of energy. This review article fosters the dialogue among the various experts in biomass and trade. Biomass-based energy can only be achieved by interdisciplinary integration of all aspects from agronomy and forestry, industrial ecology to technology development, government policies and international trade.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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