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Physic Nut: A Proactive Climate Change Risk Management Strategy

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Review Article

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ABSTRACT

Regardless of the regional variability in the causes and effects of Climate Change, it poses a major threat to both global human and ecological survival. Therefore, adapting and mitigating its consequences require an integrated approach which is not mutually exclusive of any specialization as enshrined in the Kyoto protocol. This paper reviews the concept, cause, impacts of climate change *vis-a-vis* the cultivation and viability of *Jatropha curcas* plant as a pro-active adaptation and mitigation method to Climate Change phenomenon. The paper underscores the potential contributions of the plant and its mitigating potentials against global warming to the Economy. The paper concludes by emphasizing the need for sustained population enlightenment on the benefits of *Jatropha curcas* cultivation for climate change mitigation.

Keywords: Global warming; Jatropha curcas; adaptation; mitigating effects;

1. INTRODUCTION

Climate refers to the average weather conditions of a given geographical area studied over a period of time (usually some 35/40 years), (Britannica Concise Encyclopedia, 2010). Usually, parameters such as temperature, rainfall, humidity, wind (Speed and direction), evaporation, evapotranspiration, etc.) are used in expressing weather conditions. It is when noticeable changes are observed that, experts bring this to the notice of mankind. Therefore, climate

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change could be termed as the changes/ variations in all the atmospheric elements over a period of time.

There are several factors leading to climate change, these are both man-made and natural. Increased anthropogenic activities worldwide have contributed to the high increase in the rate of gaseous emissions into the atmosphere in recent times. As a matter of fact, this constitutes the major source of atmospheric pollution and it is also a fact that pollution is one of the major causes of climate change (Hart, 2005). These anthropogenic forces lead to addition of greenhouse gases, sulphate aerosols or black carbon to the environment via changes in land usage. In addition, the natural phenomenon of climate change could be due to change in the sun energy or earth orbital cycle (*www.geocraft.com*).

The impact of climate change is multidimensional, for instance, the Stern Review (2006) and the Inter-Governmental Panel on Climate Change (IPCC, 2007). Fourth Assessment Reports state the adverse impacts of climate change on people's health, safety and livelihoods. Interestingly, IPCC predicts that damage caused by climate change could cost developed countries up to 2% of gross domestic product (GDP). The predicted climate change will create barriers to future poverty reduction and reverse many of the important socio-economic gains made by developing countries. Although, these countries according to the World Bank are some of the poorest and most vulnerable; yet are often rich in natural capital, ecosystems, and biodiversity that can contribute to solutions as they can to Climate Change. It should therefore be noted, that Climate Change knows no borders and those without forests may even be greater victims and perhaps find it more difficult to adapt (Maathai, 2009).

It is interesting to note that most rigorous mitigation will not prevent near-term impacts, because significant temperature rises and climate change are already locked in from past emissions. This makes the case for vigorous adaptation measures to be in place over the next few decades to improve the resilience of vulnerable communities. There is therefore the need to continuously enlighten the populace about the environment, its quality and the impact of mans' habits and attitudes on its sustained quality. Practices like tree planting exercises (i.e. Afforestation and Reforestation schemes) should be augmented with policy decisions like affordable pricing for kerosene as fuel in domestic cooking to safeguard our forests (Abdullahi et al., 2009); and massive investments into alternative energy sources by forward looking nations to drive their economies should be encouraged (Nigerian Tribune, 2010). This is necessary because deforestation and degradation of forests are responsible for 20% of global greenhouse gas emissions (Greenpeace, 2005).

Rapid socio-economic changes in some developing countries like India, China, etc, are influencing dramatically the fuel consumption pattern world over (Bhangale and Mondal, 2011; Tewari and Mondal, 2011; Tandon et al., 2011). Therefore, a type of development that meets the needs of present generation without compromising the ability of future generations to achieve their own needs should be sustained. It is well known that CO_2 released by petroleum diesel was fixed from the atmosphere during the formative years of the earth, those released by vegetable oils gets continuously fixed by plants and may be recycled by the next generation of crops (Mondal et al., 2008; Mondal et al., 2011b). This study therefore, examines a proactive adaptive method to Global Warming /Climate Change effects via the cultivation of *Jatropha curcas* plant. Cultivation of Jatropha curcas promises to simultaneously combat desertification, produce bio-diesel and enhance socio-economic development of the rural environments (Francis, et al., 2005; Achten et al., (2008b). Also, to address the problems of gradual depletion of the world's petroleum reserves, steep price hikes and the effects of exhaust emissions on environmental pollution, there is an urgent need for suitable alternative fuels for use in diesel engine (Mondal et al., 2008).

1.1 Factors Which Stimulates Climate Change

Gases that trap heat in the atmosphere are often called greenhouse gases. These gases (including carbon dioxide, water vapour, nitrous oxide, methane, halocarbons, and ozone) are transparent, hence sun energy passes through the atmosphere to the earth surface and the energy is absorbed by the Earth surface and used for photosynthesis by plants or emitted back to space as infrared radiations. Some of these radiations will be absorbed by greenhouse gas molecules and re-emitted in all directions and subsequently warms the earth surface by more than would be achieved by incoming solar radiation alone. This atmospheric greenhouse effect is the warming process that raises the average temperature of Earth to its present 15^0C (Ebi et al., 2003). Gases like CO_2 occur naturally and are emitted to the atmosphere through natural processes and human activities. Other greenhouse gases (e.g., fluorinated gases) are created and emitted solely through human activities. Note that emissions vary across nations, depending on the population, economic state, transportation distances and temperatures that entail cooling and heating in buildings. Although Africa as a continent contributes less than 4% of the total global greenhouse gas emissions, it is among the most vulnerable to climate change (APF, 2007). Figure 1, shows an example of CO_2 emission rates by the G8 countries for the year 1990 and 2008.

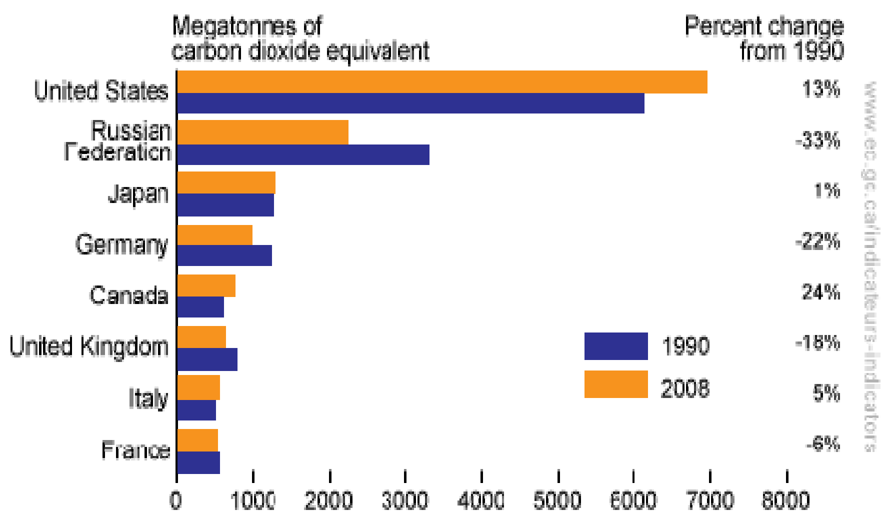

Fig. 1. Greenhouse gas emissions for the Group of Eight (G8) countries, 1990 and 2008.

Source: The Greenhouse Gas Inventory Data Interface, United Nations Framework Convention on Climate Change (UNFCCC) and the UNFCCC National Inventory Submission 2010. Adapted from: http://yosemite.epa.gov/OAR/globalwarming.nsf/content/index.html

2. GREEN HOUSE EFFECT

A typical and easily understandable description of the green house effect is given by what happens when a car is parked outside in the sun. The interior part of the car becomes heated up (Oyegun, 1982). Indeed, studies have shown that items such as candle sticks, petroleum jelly (Vaseline) and the like can melt depending on the time of the day and length of parking. Hence, the sunray that enters the car gets trapped inside the car. Thus, the sunray which comes in the form of short waves becomes heat in form of long waves, which cannot escape through the glass of the car. The trapped radiation is what generates the heat that melts the candle and damages some other items kept in the car. This is similar to what happens on earth when climate changes, i.e. the short waves (sunrays) trapped on earth becomes heat in form of long waves, which then warms the earth.

A similar description of the green house effect (i.e. when greenhouse gases prevent heat from escaping the earth's atmosphere) can also be likened in much the same way to the behaviour of the glass panels of a greenhouse, which allows sunlight in but traps in heat (Environment Canada, 2010). Pidwirny (2006) noted that, without the greenhouse effect life on this planet would probably not exist as the average temperature of the earth would be chilly -18^o Celsius, rather than the present 15^o Celsius. Without this warming, earth's diurnal temperature range would increase dramatically and the average temperature would be about 33^{o}C colder (Burroughs, 1996).

3. GLOBAL CLIMATE CHANGE: PAST, PRESENT AND FUTURE

3.1 The Past

The major contributors to greenhouse gas include carbon dioxide and water vapour. Other minor contributors which have long residence time in the atmosphere and heat trapping abilities includes – methane, nitrous oxide, chlorofluorocarbons (cfc), etc. Due to Industrial revolution, the concentration of carbon dioxide in the atmosphere has increased geometrically from the use of huge volumes of fossil fuels in the form of gasoline, oil, coal and natural gas that are consumed every day. In addition, CO_2 also enters the atmosphere through solid wastes, tree and wood products, and also as a result of other chemical reactions (e.g., manufacture of cement). It is interesting to note, that the concentration of methane has also risen due to increased cattle production, rice cultivation (292,000 to 3.08million harvested acres between 1895 to 2000, and a reported highest national average yield of 6240Ib/A in the USA, (Snyder & Slaton, 2001) and by the decay of organic wastes in municipal solid waste landfill releases; while nitrous oxide concentration was as a result of automobile emissions, solid waste and during agricultural and industrial activities.

3.2 World Population Growth

The major concern about population growth today is the rate of growth. Before the agricultural revolution, world population was between 1 and 5 million. At that time, development was mainly along the riverine areas. World Population gradually rose to about 20 million and became 30 million some 2000 years ago. During these early periods, the rate of population increase was between 6 and 10% per 100 years. By 1650 just before the agricultural revolution, world population was estimated to be between 470 and 545 million. By 1750, agricultural revolution had been established and indeed the industrial revolution had started (Table 1).

While it took about 2000 years (1850) for world population to reach the first billion, it took only 100 years to get to 2 billion. Indeed, the next 1 billion was added in only 20 years and the next in 11, and 9 years respectively. The rate of growth, pattern of living, energy consumption and so on, therefore became the real issues. This shows that the increasing human growth has structured the increasing demand for all social amenities and food. There was pressure on land resources as well as increasing demand for energy to power various machineries. In addition, Harrison (1993) put forward that the environment also serves as the sink for wastes, and human beings produce the greatest amount of wastes (i.e., Fossil and Industrial emissions, inert and municipal wastes). With most of the increases are occurring in the developing nations of the world.

Table 1. World population growth and doubling years

Year	World Population (Billion)	Population doubling years
1850	1.0	-
1950	2.5	100
1970	3.6	20
1981	4.4	11
2000	6.0	19
2009	6.77	9

Source: Orire and Olorunfemi, (2009).

3.3 The Present Effects

However, with increase in human population, increasing industrialization and transportation and increased consumption of hydro-carbon, the emergence of petrochemical industries; chlorofluorocarbons (CFCs) gases used in refrigerators; nuclear power and generation of carbon monoxide have resulted in the increased production of ozone depleting gases. These ozone depleting gases and some photochemical reactions tend to reduce the ozone layer. In other words, there is a reduction not only in its thickness, but in addition, it also punctured holes in the ozone layer. The consequence is that ultra violet rays which hitherto was absorbed by the ozone layer now has the opportunity of direct access to earth. This has led to increase in the occurrence of skin cancer and increased temperature.

Huge volumes of fossil fuels in the form of gasoline, oil, coal and natural gas that are consumed everyday end up releasing carbon dioxide into the atmosphere. These emissions generated by human activities accentuate the natural ‘greenhouse effect’. The unprecedented speed of change in greenhouse gases and effect is threatening social and environmental systems that cannot adjust at the same pace. More extreme weather events are occurring worldwide, sometimes in unexpected ways – such as the flooding events in the dry regions of Ethiopia in 2007, in Brisbane, Australia (2010), (i.e. flood and windstorm events together from 1900 to 2006, accounted for 56.7% and more than 21.7% of the total number of disasters and of fatalities, (UNESCO, 2009); the 1995 heat wave that caused 514 heat-related deaths (12 per 100,000 population), and 3300 excess emergency admissions in Chicago, USA (Whitman et al., 1997); desertification in Africa has reduced by 25% the potential vegetative productivity of more than 7million km^2, or one-quarter of the continent’s land, (UNEP,1997); changes in the onset and cessation of the rainy season in Nigeria and other parts of Africa; drying up of some rivers and reduced productivity of some agricultural lands etc. A false start of the rains for example, may lure farmers to plant crops early and this can turn out to be disastrous for them if the first rains are followed by a long period of drought (Adejuwon and Odekunle, 2004).

The great loss suffered by farmers practicing “dry farming” especially in the dry belt of Nigeria, resulting from false onset of the rainy season is a common phenomenon. It is noteworthy that, while only 2.6 to 4% of farmland in sub-Saharan Africa was prepared for irrigated farming, it is as high as 40% or more in some Asian countries as at 2008 (AFP, 2011). This makes them more vulnerable to climate change impact. Farmers should therefore be less dependent on rain fed agriculture. It should be noted that transition from one system of agricultural practice to another requires planning and persuasion before implementation. The Nigerian Government at a time encouraged the use of other alternative sources of energy especially in cooking rather than wood fuel. However, because of inconsistencies in Government policies, the price of both kerosene/gas which hitherto was encouraged has gone out of the reach of low income earners. The result has been increased dependence on wood as a source of energy. The effect is that there is a reduction in the plants that naturally convert carbon dioxide into useful raw materials (oxygen). Given the legacy of greenhouse emissions and rising global energy consumption, further warming is unavoidable. The United Nations Intergovernmental Panel on Climate Change (IPCC) reported that some changes may be sudden and irreversible. Developing countries, with less technical, economic and institutional capacity to adapt are likely to find it hardest to cope.

3.4 Future Climate Change Effects on Our Environment

Apart from the two major effects of global warming, that is – Increasing temperatures and Rise in Sea level, other noticeable future and present impacts within our environment are as follows:

Disappearing African Rivers: Geologists recently projected a 10-20% drop in rainfall in North Western and Southern Africa by 2070. That would leave Botswana with just 23% of the surface-water flow it has now, Cape Town with just 42% of its river water (National Geographic, 2006).

1.2 billion People could experience freshwater scarcity by 2020; crop yields in central and south Asia could decrease by 50% between now and 2050; and coastal communities, coastal and marine ecosystems, and even entire island nations could vanish (ADB, 2007).

More floods due to increases in “intense rainstorms” across (i.e. 2010 Pakistan and Brisbane, Australia Floods, Sokoto, Kebbi, Jigawa and Lagos States floods in Nigeria) due to change in precipitation patterns (ReliefWeb, 2011).

Mangrove Trees: Rising Sea Levels linked to climate change may result in losing half of the mangrove trees of the pacific isles by end of the century (UNEP, 2006).

Wetlands and Coral reefs are threatened. About 24-30% of Asia’s reefs are likely to be lost by 2050 (ADB, 2007).

Destabilization of ocean currents, i.e; via a slowdown of the thermohaline circulation trigger localized cooling in the North Atlantic and lead to cooling, or lesser warming in areas warmed by the North Atlantic drift like Scandinavia and Britain www.en.wikipedia.org.

Increasing temperature will mean northward migration of mosquitoes and malaria fever which will extend from the tropical to warm temperate region while the sporogony of the protozoa causing the malaria accelerates from 25 days at 10^0 C to 8 days at 32 ^{0}C (IPCC, 1998; Odjugo, 2000; DeWeerdt, 2007). About 200 million people could be affected by sea level rise, especially in Vietnam, Bangladesh, China, Indonesia, Thailand, Philippine, Indonesia, Nigeria and Egypt (*www.en.wikipedia.org*).

Climate change negatively affects biodiversity conservation and management through exacerbated drought conditions, increased risk of wildfires leading to some extreme events like heat, waves, river and coastal flooding, landslides, storms, hurricanes and tornadoes which culminate in environmental degradation (Agbogidi, 2011). So to fight these challenges, increase in the productivity level of pollution free product by application of advanced, environmental friendly technology, which can manage and allocate efficiently all resources for sustainable development of agriculture, is necessary (Basu, 2011; Bhadoria, 2011; Mahapatra, 2011; Mondal et al., 2011a).

3.5 Impact of Climate Change on French Wine Production

Impact of green house gas emission may result in the displacement of vineyards more than 1000km beyond their traditional boundaries by the end of this century (reducing up to 60^0 North and 50^o South, except for continental interiors) thereby radically jeopardising the wine-growing industry (Greenpeace, 2010). Additionally, the average annual temperature has significantly increased in the Burgundy region over the last years, leading to major shifts in the wine production calendar. Already with the above points; it is interesting to note that Wines have already lost elements of their specific personality: they are marked by higher alcohol strengths and sugar content. These changes put France's wine producing pedigree at risk. A culture that has taken centuries to build is now in peril and might even disappear completely (Greenpeace, 2010).

4. THE WAY FORWARD: A PRO-ACTIVE ADAPTIVE METHOD TO CLIMATE CHANGE IMPACTS INCLUDES ENCOURAGING THE CULTIVATION OF *JATROPHA CURCAS*

Jatropha curcas whose origin was traced to Mexico and Central America is traditionally known, in many subtropical and semi-arid regions for its medicinal properties (Kumar and Sharma, 2008). This small multipurpose deciduous tree (up to 5m), Achten et al.(2008b) is useful for the prevention and control of soil erosion, and acts as a living fence in restricting unwanted access to fields (Gubitz et al.,1999; Henning,2006; Achten et al, 2008b). It grows in a variety of environmental conditions, including poor soils (except Vertisols and Soils with pH above 9 (Achten et al., 2008b) because of its high adaptability (Heller, 1996), but generally prefers heat of the tropics and subtropics. It grows without irrigation in a wide range of rainfall conditions, from 300 – 3000mm per year (Achten et al., 2008a). Jatropha curcas, which is normally propagated by seed or stem (seed propagation is preferred above vegetative propagation (cuttings) if establishment of long living plantation is intended (Heller, 1996; Achten et al. 2008b), has a gestation period of between 30 and 50 years. The seeds become mature, when they change from green to yellow. Seed production ranges from about 2 tons per hectare per year to more than 12.5 tons per hectare per year, after 5 years of growth (El Gamassy, 2008). In addition, Jatropha is grown in plantations with tree densities ranging from 1,111 to 2,500 trees per hectare (Achten et al., 2008a; Lele, 2008) depending on the spacing. The fruits are harvested manually because of uneven ripening (Heller, 1996; Achten et al., 2008b). It is also called physic nut which is used to produce non-edible oil (due to presence of toxins as phorbol esters, trypsin inhibitors, lectins, phytates (Francis et al., 2005) use in the production of biodiesel. It has been established that most of the parts of the plant from the leaves, roots, latex, and seeds to its twigs, are useful for various human and fauna needs.

4.1 Other Uses of Jatropha

Most of the parts are useful as follows:

i. The whole plant is planted to prevent water erosion and conserve soil. It provides an efficient live fence and can be used as green manure. The plant possesses allelopathic properties i.e., it suppresses growth of unwanted plants nearby.
ii. The Roots are used as ethno-medicine.
iii. The Leaves are used as ethnomedicine and yields a tan and brown dye.
iv. The Plant's Latex can be used for making ink and it resembles shell (30-40 %).
v. The Plant's seed / oil is a source of diesel fuel (37% content). It is used as lubricants in soap. And as illumination and in making candles.
vi. Its twigs are used as medicine and can be used as natural tooth brush.

Source: El Gamassy, 2008.

Jatropha is acclaimed as a promising biofuel crop, ideal to convert today's unproductive lands into tomorrow's green oil fields. It also proves to be a promising biofuel plantation, which could emerge as a major alternative to diesel, reducing world dependence on oil imports and saving foreign exchange, aside from providing much – needed energy security (El Gamassy, 2008), and helps in the fight against global warming. Jatropha can bring significant environmental benefits. It can replace jet fuel and diesel from petroleum without interfering with food crops or leading to the clearing of forests. It also assists in the afforestation and fight against desertification when planted in the form of hedges in some frontline states in Northern Nigeria (GEXSI, 2008). The oil-rich seeds are very attractive feed stock for biofuel production. The kernel which consists of about 60% oil can be transformed through esterification into biofuel. Also, the green energy of the plant can be used to power machines while the biofuel mix was reported as being more efficient and burn less fuel in total than the conventional one. Jatropha oil produced lower nitric oxide levels in comparison to diesel (Mondal et al., 2008). It burn with clear smoke-free flame. In this light therefore, Global biofuel production has tripled from 4.8 billion gallons in 2000 to about 12.6 billion gallons in 2007 (El Gamassy, 2008). However, it still accounts for less than 3 percent of the global transportation fuel supply (El Gamassy, 2008). Furthermore, Jatropha equally sequesters lots of carbon dioxide from the atmosphere (Jatropha World, 2008). In addition, Seed cake remaining after oil extraction is rich in nutrients and can be utilized as fertilizer and animal feed (if properly detoxified) with an average nitrogen: phosphorous: potassium (NPK) ratio of 40: 20: 10 (Prueksakorn and Gheewala, 2008). The fruit husks can also be gasified (Vyas and Singh, 2007), fermented for biogas production (Lopez et al., 1997) or combusted directly.

4.1.2 *Jatropha curcas* cultivation

In a global view, 5 million hectares of Jatropha crop are being established on a worldwide scale, scattered across a vast number of countries (El Gamassy, 2008). With energy as the source of economic prosperity of many nations, including Nigeria and most Gulf States, and the role of the dynamics of demand and supply of energy in the global politics, many forward looking nations are investing in alternative energy sources to drive their economies. For instance, Jatropha has attracted much attention as a feedstock for large-scale biodiesel production in India (Sethi, 2003), where researchers project that up to 15 billion liters of biodiesel may be produced from the cultivation of Jatropha on 11 million hectares of wasteland by 2012 (Mandal, 2005).

Nigerian Government is strongly supporting investments schemes as well as capacity building; although it varies slightly throughout the respective states. According to GEXSI, (2008) a targeted acreage of Jatropha cultivation of 100,000 ha was slated for the year 2010, and also a guaranteed price is reported to have been introduced through the NNPC (Nigeria National Petroleum Company). Already the University of Ilorin has planted about 44 hectares of Jatropha plantation since 2009 and has further cleared land for more cultivation so as to enhance the intellectual capability, economic standing and overall environmental wellbeing of the populace. It was further affirmed through various research works by scientists in the institution, where jatropha was used to produce soap, ceiling boards, floor tiles, ink dye, animal feed, engine oil and biofuel (Nigerian Tribune, 2010). Jatropha cultivation can equally help to increase the rural incomes, self – sustainability and alleviate poverty for women, elderly, children and men, tribal communities, small holding farmers etc (Francis et al. 2005; Achten et al.,2008b; Jatropha World, 2008).

4.1.3 Mitigating effects of *Jatropha curcas* against global warming

Jatropha plant population is about 1111 or 2500 plant population/ha depending on the spacing. It was opined that a plant of Jatropha could absorb about 8kg of CO_2 /year. Hence, 1111 plants absorb about 8888kg CO_2 /year/hectare or 20,000kg of CO_2/year and for the plant lifespan of 30 – 40yrs – the absorption will be 8888kg x 30 yrs or 20,000kg x30years. Since the plant is drought resistant and perennial, it stands on the soil throughout the year.

4.1.4 Methane production

Apart from biodiesel obtainable from the plant the seed cake could be used as fertilizer and animal feed. Since the cake is toxic, numerous scientists (Joslyn, 1970; Wheeler and Ferrel, 1971; Hudson and El-Difrawi, 1979) have been working on how to detoxify the cake. Makkar and Becker, (1999) and some other scientists (Annongu, et. al. 2010) reported on the utilization of various chemical without encouraging results. But it is interesting to note that the biological method of detoxification gave encouraging results. In which the cake was incorporated with various beneficial microbes which detoxified as well as help in converting the amount of crude protein to microbial protein before it inclusion in animal feed (Belewu et al 2011). This method will help in reducing the amount of methane produce by livestock or animals feeding on such diet.

4.1.5 *Jatropha curcas* as organic fertilizer

In recent time, the value of organic fertilizer is being acknowledged. The use of inputs like inorganic manure tends to intensify greenhouse gas production (Achten et al. 2008b) and has created problems of water pollution as well as the belief that consumption from inorganic fertilizer causes Cancer. Utilization of organic fertilizer will prevent ground water pollution caused by inorganic fertilizer. Another benefit of organic fertilizer is that the nutrients are released more slowly than in chemical fertilizers. This slower process allows the plants to process the fertilizer in a more natural way and will not result in over fertilizing which can damage the plants. Organic fertilizer also helps to improve the soil structure by enhancing its moisture retention capacity and long-term fertility. Hence, the use of organic manure from Jatropha could help in encouraging organic farming.

4.1.6 ***Jatropha* as erosion control and soil improvement**

Jatropha "living fences" not only control unwanted access to the fields, they also reduce land erosion and, if planted parallel to slopes to fix small earth or stone dams, they help control water erosion. The plant's roots grow close to the ground surface, anchoring the soil like miniature dikes or earthen bunds. These dikes, effectively slows surface runoff during intense downpour, thus causing more water percolation into the soil and boosting harvests. Other Expected results for Jatropha biodiesel culled from Achten et al. 2008b are:

Impact on Soil: (i) Erosion control and Carbon sequestration are the most positive impact, but (ii) negative impact if intensively grown with high input of fertilizers and machinery. Impact on vegetation structure: (i) positive if wasteland is reclaimed (ii) negative in case of re- allocating (semi -) natural vegetation to jatropha.

Impact on biodiversity: (i) negative in monoculture. Improvement possible by intercropping, agroforestry and set aside part of the land. (ii) Positive in case of low use of biocides. (iii) Further, there are some unchecked reports on invasiveness.

Impact on water: positive on-site effects, but negative off-site effects, (although further research necessary), Heuvelmans et al. (2005).

5. CONCLUSION

Policy makers should assist producers in their efforts to manage risk and adapt to climate change. Policy and programmes should not be designed in isolation but need to recognise the importance of an integrated approach. Flexibility in policies and programmes is crucial to ensure diverse needs are met from conditions in various types of commodity production, farming systems, biophysical environments, and personal circumstances. The agricultural sector faces increasing challenges from climate and weather risks hence governments should develop appropriate policy to enhance producers' adaptive capacity (Milestad and Darnhofer, 2003). Furthermore, many climate and weather risk management strategies fit squarely into sustainable agriculture practices and can, therefore, be promoted with several of the programs and policies targeting environmentally responsible production. Hence, the adoption of the *Jatropha curcas* cultivation as a form of sustainable agricultural practice, poverty alleviation and as a weather/climate risk management strategy is thereby recommended. Also efforts should be made to adequately raise the living standards of the poor so as to minimise the incidence of environmental degradation caused by poverty. Adequate reduction in population is essential for environmental sustainability and poverty reduction. Incentives should be given to people to reduce birth rates

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