A REVIEW OF ENVIRONMENTAL EFFECTS ON SUGARCROPS

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ABSTRACT

Sugarcane is the second most important cash crop of Pakistan after cotton, belonging to *Saccharum* species. It is noted that patterns of trade influence elements of sugar production that have an impact on the environment. It is not the main intention to compare cane and beet systems, although comparisons are sometimes made for contextual purposes. The environmental impacts of the processing (but not cultivation) of sugar crops have been summarized previously and other texts on aspects of sugar production often include some coverage of environmental issues. However, this appears to be the first attempt to collate and review information on the environmental impacts of sugar production. The emphasis is on an environmental perspective although agronomic priorities are generally acknowledged where appropriate. The one area where a consistent difference in viewpoints has become apparent is in relation to soil quality. From an environmental perspective, soil nutrient balance is seen as degradation; this only tends to be the case from an agronomic perspective when the effect is sufficient to reduce yields. There appears to be a lack of data on air pollution (and human health impacts) arising from poorly managed aerial application of agrochemicals. Similarly, short-term water pollution events arising directly from an application of fertilizer or pesticide appear not to be reported. In broad terms, the literature on environmental aspects of cane sugar production is dominated by contributions from Australia, South Africa and to a lesser extent India, Mauritius and Pakistan. This should not be taken to suggest that environmental impacts, or measures to reduce them, are necessarily of greatest significance. The purpose of this review is to study environmental effects (ongoing cultivation, water, soil and air pollution) on sugarcane crops.

INTRODUCTION

Sugarcane, a tropical grass resembling bamboo and belonging to the Saccharum species, stores sucrose in its stem. There are two confirmed wild species, *S. spontaneum* found in tropical Oceania, Asia, and Africa, and *S. robustum* limited to Papua New Guinea and neighboring islands. The domesticated species include *S. officinarum* (noble cane, one of the first cultivated for chewing, now grown in limited locations), *S. edule* (found mainly in Melanesia and Indonesia), *S. barberi* (used for the first sugar production) and *S. sinense*. Most commercial sugarcane varieties are hybrids resulting from selective breeding of these species, which has significantly increased cane sugar yields from 1-1.5 t/ha to 8-17 t/ha during the 20th century, benefiting the sugar industry. The sugar industry is often praised for its positive environmental features, including the remarkable efficiency of sugarcane in converting solar energy to biomass. Sugarcane has the highest harvest index among all crops, meaning it utilizes a large proportion of the material grown in the field. This exceptional efficiency is attributed to several factors, as described by Alexander (1985) and Payne (1991).
Firstly, Saccharum species, including sugarcane, readily interbreed, providing a wide range of options for plant breeders and facilitating the spread of adaptive traits. Furthermore, sugarcane and related species employ the C4 photosynthetic pathway, which allows them to exploit lower concentrations of carbon dioxide and a wider range of light intensities, while eliminating photorespiration. Sugarcane has also been shown to utilize a broader range of wavelengths of solar radiation

within the visible spectrum compared to most plants. Physiological adaptations, including the use of sucrose as a principal photosynthate for easy carbohydrate translocation, contribute to the efficiency of sugarcane in fixing solar energy.

As a result of these adaptations, sugarcane fixes approximately four times as much solar energy as most temperate crops, leading to a yield potential of around 50 t dry matter/ha/year. This is supported by Paturau (1989) and UNEP (1982), which estimate that 1 million kcal of energy in the form of sugar requires only 0.07 ha of sugarcane for production, whereas the same amount of energy in the form of beef requires 7.70 ha. These findings highlight the remarkable yield efficiency of sugarcane as a crop, further emphasizing its positive environmental characteristics.

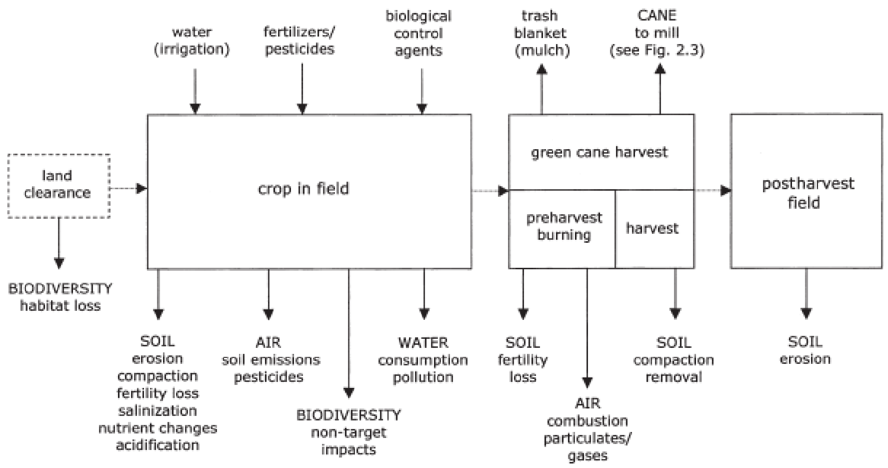

Figure-1 Sources of environmental impacts relative to key processes and inputs in the cultivation of sugarcane

Impacts on ongoing Cultivation

Sugar crop cultivation can have environmental impacts that extend beyond the farmer's field, potentially affecting biodiversity. These impacts can include waterway sedimentation from soil erosion and eutrophication resulting from nutrient leaching and runoff. Areas under cultivation generally have lower levels of indigenous species compared to adjacent natural habitats, although crop and soil invertebrates can exhibit considerable diversity, and micro-organismal biodiversity is often overlooked. The use of pesticides can directly harm non-target organisms and indirectly affect other species that rely on them for food or shelter. Inappropriate biological control methods, such as the introduction of non-native species like the mongoose in the Caribbean or the cane toad in Australia, can also have negative biodiversity impacts. However, responsible biological control programs can have positive effects. Concerns have been raised about the potential biodiversity impacts of cultivating transgenic crops, including sugar beet.

Impacts on Water

Cane cultivation is heavily reliant on irrigation in many areas, which has raised concerns about the increasing quantities of water used. In Pakistan, for instance, cane cultivation is seen as putting pressure on available groundwater resources. Similarly, in Australia, water extraction for cane irrigation has led to the overuse and degradation of river systems. Cane is known for its highwater consumption, with an estimated 7.5 Ml/ha of water needed for a cane crop of 100 t/ha. This demand can only be met by rainfall in some areas, leading to substantial irrigation requirements in others. Unfortunately, irrigation systems are often found to be inefficient, resulting in water wastage. Irrigation may also exacerbate other cultivation impacts, including soil salinization. While sugar beet is relatively insensitive to soil moisture, around one-fifth of the world's beet cultivation is still irrigated, which may be essential in some dry areas but provides little benefit in others.

The cultivation of sugar crops can result in pollution of watercourses and aquatic habitats due to agrochemicals and sediment runoff. Additionally, fertilizers applied to the crops may lead to nutrient leaching and contamination of ground water. These impacts can have far-reaching effects on downstream ecosystems, such as coastal zones. While examples of water quality impacts from cane cultivation are found in areas where the crop is grown, such as Australia, South America, and the USA, it can be challenging to attribute these impacts solely to cane growing due to other land uses. Similarly, concerns have been raised regarding beet cultivation, but it is difficult to pinpoint water pollution specifically to the cultivation of this crop since it is only one component of a broader crop rotation.

Impacts on Soil

Cultivating cane on slopes and leaving beet fields bare over winter are practices that can increase erosion risks, particularly in certain areas. The extent of erosion problems varies depending on local conditions. Soil erosion losses under sugarcane have been estimated to range from approximately 15 to over 500 tons per hectare per year, depending on the study (Prove et al., 1995). Beet fields left bare over winter can be vulnerable to both wind and water erosion, with estimates of soil losses ranging from 13 to 49 tons per acre per year due to wind erosion in the USA and 0.3 to 100 tons per hectare per year due to water erosion in European beet-growing regions (De Ploey, 1986; Morgan, 1986).

Harvesting crops can result in soil being removed from the field, in addition to erosion. In sugarcane cultivation, about 1-15% of the material delivered to the mill may consist of extraneous material, including soil. However, the nature of beet harvesting leads to larger quantities of soil being removed from the crop. Studies have estimated a soil 'tare' of 10-30% for harvested beet, with some suggesting soil losses of 9 tons per hectare per harvest (Poesen *et al*., 2001). Over large areas, these losses can accumulate to substantial amounts, with published estimates indicating 3 million tons per year for the EU and 1.2 million tons per year for Turkey alone (Oztas et al., 2002). Sugar crop cultivation can result in soil compaction, which increases bulk density and reduces porosity, negatively affecting soil fauna. Reduced porosity also leads to increased runoff, which exacerbates erosion problems. The risks of compaction associated with cane and beet cultivation differ according to the cultivation systems used (monoculture and rotation, respectively). Beet cultivation poses particular concerns due to the number of field operations used in field preparation and the fact that soils are often wet during harvesting. Sugar crop cultivation can also lead to other soil quality impacts, such as loss of soil organic matter, changes in nutrient levels, salinization, and acidification. Loss of organic matter and changes in nutrient levels occur in both cane and beet cultivation. Salinization, which is associated with poor water management and drainage, and acidification, mainly resulting from the application of inorganic fertilizers, are more prevalent in certain cane-growing areas than in beet cultivation. Combined impacts on soil quality can lead to a loss of fertility which is generally grown as a continuous monoculture. Several countries have experienced a decline in cane yields due to the loss of soil fertility.

Impacts on Air Quality
Air Pollution

Burning cane before harvest results in air pollution and contributes to environmental impacts. Additionally, the application of fertilizers can worsen nitrogenous emissions from sugar crop fields. Burning bagasse as a fuel source for cane processing operations can lead to unwanted emissions, although this is a form of utilizing a by-product and may be a more environmentally friendly option than other alternatives. The wastes produced during the processing of cane and beet can also cause significant odor issues due to the emission of noxious gases.

The environmental impacts of the processing of sugar crops are summarized below, and their sources relative to key processes and inputs are illustrated in Figure-2 (for cane) and Figure-3 (for beet).

Positive Environmental Aspects of Sugar Production

Crop characteristics

Sugarcane is known for its high productivity in terms of yield per unit area and per unit of water consumed. Due to its ability to fix large amounts of atmospheric carbon, it has gained interest as a renewable fuel source, whether in the form of biomass or alcohol. The use of bagasse, the waste fiber from cane processing, as a fuel source in many regions has already made cane sugar production relatively carbon-neutral. Although sugar beet does not have the same level of productivity as cane, it has been explored as a potential biofuel source due to its efficient root system, which allows it to scavenge nutrients effectively.

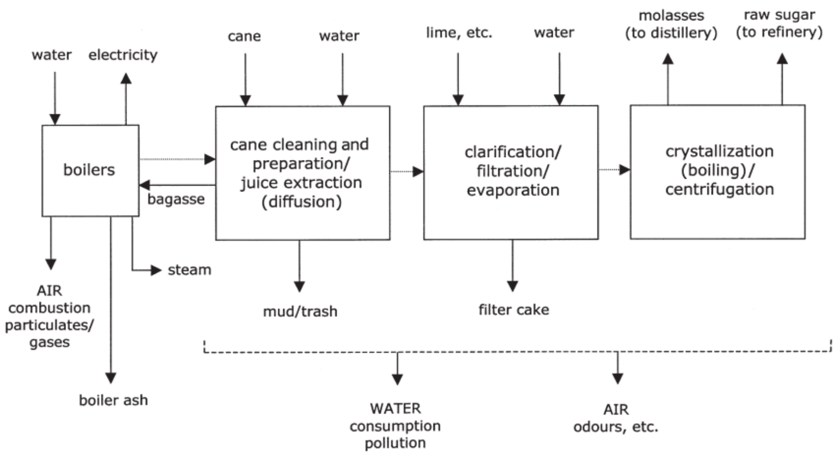

Figure-2 Sources of environmental impacts relative to key processes and inputs in the processing of sugarcane

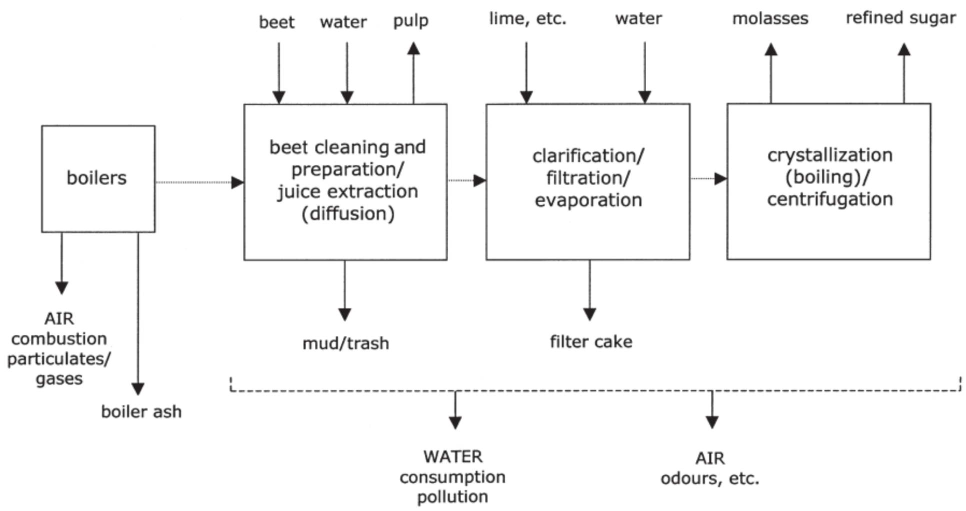

Figure-3 Sources of environmental impacts relative to key processes and inputs in the processing of sugar beet

By utilizing waste materials generated from sugar cultivation and processing, particularly from cane, the amount of waste output can be reduced, potentially mitigating the negative impacts of other sugar production activities. Utilizing by-products instead of environmentally damaging alternatives, such as mulches or soil amendments, can also have positive environmental effects. The burning of bagasse as a renewable fuel to generate power, for instance, can replace the consumption of fossil fuels. It should be acknowledged, however, that the utilization and further processing of by-products can have negative environmental consequences, making an overall cost-benefit analysis complex. Such concerns extend to waste and by-products from secondary processing activities. For instance, the use of molasses as a feedstock for alcohol production creates a secondary waste material, vinasse, which may be either a pollutant or a valuable by-product, depending on how it is handled.

Reducing the environmental impacts of Sugar Production

The effectiveness of measures to mitigate environmental impacts can be maximized when they are incorporated into a comprehensive and practical system of sustainable management. The subsequent sections outline several measures that can be implemented to address the diverse environmental impacts of different activities. The responsibility for natural resource management should be shared transparently between the government, the community, and the sugar industry. Appropriate incentives should be established to promote the protection of natural resources and their use in an ecologically sustainable manner, with a mix of motivational, voluntary, property-right, price-based, and regulatory instruments tailored to the specific issue and local, regional, and social characteristics. The community, along with natural resource users and beneficiaries, should contribute to providing incentives to sugar producers who are primarily responsible for protecting the environment.

CONCLUSION

Sugar is a product that most of us consume on a daily basis. Sugar production contributes to development in many poor countries, by producing employment and reliable incomes for many, there are a range of negative issues associated with its production. The demand for sugar has continued to rise steadily, increasing by about 70% in total since 1980. The environmental impacts of sugar production have been largely ignored. Sugarcane plantations in many tropical and sub-tropical countries have led to perhaps the largest losses of biodiversity of any single agricultural product.

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