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Reducing Carbon Emission in the Food and Agricultural Industry: A Case Study of Sustainable Rice Production

Ukwueze Okechukwu Godwin Ugo

Department of Educational Foundation, University of Nigeria Nsukka

ABSTRACT

Food and agriculture constitute vital components of human wellbeing, hence, sustainable management of soil and agriculture are critical to achieving world stability. However, agricultural activities which include crop and livestock production for food, contribute to emissions in a variety of ways. Currently, there are many concerns about the sustainability of development strategies, intensified by the encroachment of local, regional and global climate change. Consequently, a lot need to be done to rein in and reverse the drivers of climate change and to modify policies and incentives to modify current resource use out of consideration for the needs of future generations. This paper therefore examined the need for rice to be cultivated in a sustainable manner. The sustainable strategies suggested in this study do not suffice as a complete way-out to the constraints of climate change; however, they can contribute to more positive economic and environmental improvements, with several benefits directed towards improve soil health and agricultural sustainability for generations to come.

Keywords: Food, Carbon emission, Agriculture, Irrigated Rice, Sustainable Production.

INTRODUCTION

Food and agriculture constitute vital components of human wellbeing, hence, sustainable management of soil and agriculture are critical to achieving world stability. However, agricultural activities which include crop and livestock production for food, contribute to emissions in a variety of ways. According to Grünberg, Nieberg and Schmidt [1], the sector contributes about 14%, and the food system about one-third of anthropogenic greenhouse gas (GHG) emissions. Of specific interest is irrigated, lowland rice cultivation, which covers about 56% of the total rice-cropped area, and produces about 76% of the world's total rice crop. This staple food provides about 21% of humans' caloric energy and about 14% of their total dietary protein, even though rice is not a concentrated source of protein [2]. The irrigated production methods that generate three-fourths of our supply of rice are widely regarded as being eco-unfriendly, specifically in the following ways: These methods consume between a quarter and a third of the world's freshwater resources currently utilized, amounting to about half of the agriculture sector's annual irrigation use. Over-extraction of groundwater for pumped irrigation to support rice and other production is lowering water tables, by 1–3 $m \cdot yr^{-1}$ in some parts of China and by up to 1 $m \cdot yr^{-1}$ in several parts of India [3]. Also, the use and overuse of inorganic N and P fertilizers for rice production contribute to soil and water contamination, as does the application of many agrochemical biocides to control rice crop pests and diseases. Irrigated rice paddy fields are a major source of anoxic methane (CH_4) emissions as well as other greenhouse gases (GHG) that are driving climate change and global warming [4]. These detriments, however, need not impinge upon the productivity and sustainability of the agro-ecosystems as much as they do at present. This is because these negative effects can be significantly reduced by making certain simple, inexpensive, and indeed often cost-reducing changes in the standard agronomic practices for growing irrigated rice.

The System of Rice Intensification

These changes were first assembled some 30 years ago in Madagascar under the rubric of System of Rice Intensification (SRI) [5]. Although some of them are counterintuitive, SRI changes in the ways that rice plants, soil, water and nutrients are managed can elicit more productive and robust phenotypes from most rice varieties, while also conferring concomitant environmental benefits [6]. Because these changes raise crop yields at the same time that they lower production costs, farmer's net income ha−1 is raised by more than the improvement in yield. This increase, usually at least 25%–50% but often even more, is achieved with reduced consumption of water, with more resilience to the effects of adverse climate, and with diminished greenhouse gas emissions. While this may sound too good to be true, the beneficial effects of such improvement in phenotypes by making changes in agronomic management have been demonstrated in >50 countries [7]. These effects do not depend on farmers purchasing and using new inputs. Instead they derive from making different and better use of available, nature-based resources. Farmers do not need to procure new or different seeds because the recommended practices of SRI improve the productivity of most rice varieties, both local (traditional) and improved (high-yielding and hybrid). It is true that the latter produce the highest yields with SRI management, but local varieties often command a higher market price because of consumer preferences, and they can become more profitable with agroecological management, given that SRI methods also lower farmers' costs of production.
In the same vein, chemical fertilizers can be used with SRI alternative methods. But some of the best results are obtained just with enhancement of soil organic matter through the application of compost, mulch, or green manure [8]. This improves the structure, functioning and biological benefits of soil systems in ways that chemical fertilizer does not. SRI methodology was initially developed to benefit smallholders with very limited resources, and it is well-suited to their situation and needs. However, with mechanization, SRI can be extended to larger scales of operation [10]. Because the rice phenotypes that result from SRI management are more resistant to pests and diseases, the use of agrochemical biocides can be reduced or often even eliminated [9].
SRI management modifies standard practices for growing irrigated rice: transplanting very young and individual seedlings, reducing plant population density as well as the applications of water, seed and fertilizer. The resulting rice plants have larger, deeper, healthier, longer-lived root systems [11], while promoting the abundance, diversity and activity of beneficial soil organisms around plant roots (in the rhizosphere) and within the plants themselves. These soil organisms of immense variety and uncountable numbers, ranging from microbes to earthworms, can be referred to simply as "the life in the soil" or more formally as the soil biota. The size and health of living plant roots can be easily seen and evaluated if one carefully excavates, cleans and inspects them. Unfortunately this is seldom done as probably 95% of crop science investigations have focused on plants' above-ground organs and physiology. Roots thus remain a domain of flora incognita [12].

Roles of Soil Biota

The accompanying soil biota is considerably more difficult to grasp and appreciate than are plant roots. The mineral portion of the soil, which is what is seen with the eyes, is only about half of the total volume of healthy soil, i.e., soil which is not compressed, compacted, virtually dead. In healthy soil, the air and water in pore spaces, virtually unseen, each constitute another 20%–25% of the soil's bulk volume. The diverse and dynamic living biomass in the soil, difficult to see and assess, comprises just a few percent of the soil's volume. However, its profound importance for crop productivity can be likened to 'the tail that wags the dog' [14]. It is gradually being discovered that the maintenance of human health and growth is heavily dependent on what is referred to as the human microbiome, comprised of the trillions of microorganisms that inhabit the bodies [15]. This diverse multitude of microorganisms provides myriad services and performs multiple functions to sustain our own healthy existence. Plants are similarly benefited and protected by what is called the soil–plant microbiome [16]. One of the remarkable things that have already being learned is that some soil microorganisms, collectively called endophytes, naturally reside within plant tissues in and around cells in the roots and above-ground plant organs. Recently, it's been found that microbial endophytes can influence, beneficially, the expression of plants' genetic potentials [17]. Further, there is evidence that certain microorganisms within the soil and plant tissues can stimulate the growth of plant roots. This creates positive feedback between the soil biota and the plants' root systems, enhancing the plants' health and productivity while reducing dependence on the application of chemical fertilizers to achieve higher crop yields. For example, inoculation of rice plant roots with certain rhizobacteria can increase the roots' number, length, absorptive surface area, and biovolume, and also significantly enhance their selective nutrient-uptake ability [18]. This makes sense from an evolutionary perspective because plant growth-promotive rhizobacteria and other organisms in the soil benefit from plants' growing larger, more vigorous root systems, and they can produce phytohormones that stimulate such growth [19]. More root growth supports greater photosynthesis in the leaves, which in turn increases roots' exudation of carbohydrates, amino acids, organic acids and other utilizable nutrients into the surrounding soil that benefit soil organisms. This establishes and maintains symbiotic dynamics both below-ground and within the plant [20].

Resistance to Climatic Stresses

The more productive phenotypes of rice that result from this plant–soil–microbial interaction have more resilience to climate stresses and greater water efficiency and productivity [9]. This is attributable to their having larger, deeper root systems that can access water at lower depths within the soil profile. More life in the soil also means that the soil itself has more porosity and can absorb and retain more water—and the biota itself contains more water—than if it is depleted of organisms at multiple scales. These benefits are largely due to microbial production of hygroscopic exopolysaccharides that strongly absorb water and promote soil aggregation. A number of studies have shown SRI-grown rice plants to be more resilient to drought and water stress, as well as more resistant to storm damage and cold temperatures, summarized in [9].

A meta-analysis of published studies from eight countries reporting SRI-conventional comparison trials listed in [21] has found that SRI rice crops, probably because of their expanded root systems, can produce higher grain yield while using 35% less irrigation water per hectare, and 22% less total water ha^{-1}, i.e., irrigation plus rainfall. With increased yield, total water use efficiency (i.e., kg of rice produced per liter of water provided) averaged 52% higher in the trials, and the water use efficiency of irrigation water was 78% greater [21].

The greater water productivity with SRI crop management was demonstrated across a wide range of ecozones, in both wet and dry seasons, for the full range of soil textures and pH, and for rice varieties of short, medium and long duration [21]. A phenotypical difference in plant physiology that contributes to such results is that SRI plants produce more than twice as much carbohydrate photosynthates per unit of water transpired as do plants of the same variety grown conventionally.

Reductions in Greenhouse Gas Emissions

The fact that irrigated SRI plots have less net emission of greenhouse gases is a bonus, reducing the global warming potential contributed from irrigated rice paddies (in CO_2 equivalence). It is expected that microbial-production of methane (CH_4) emissions will be reduced when paddies are no longer kept continuously flooded. But with SRI management that can reduce the need for synthetic fertilizer N applications, there are not offsetting increases in nitrous oxide [N_2O] emissions, and sometimes there are even small reductions as the substrate for microbial production of N_2O during denitrification is diminished [2]. An evaluation done in Andhra Pradesh state of India calculated that with SRI rice management, compared to current practices, GHG emissions were reduced by 40%, groundwater extractions by 60%, and fossil fuel consumption by 74% [14].

CONCLUSION/RECOMMENDATION

Changes in age-old practices have been resisted, more by some scientists than by farmers, but there is now acceptance of SRI practices by major international development organizations like the World Bank, FAO, the International Fund for Agricultural Development, and UNEP. The methods have also been adapted with similar results for rainfed (unirrigated) rice production, although not with the same reductions in magnitude of GHG emissions. Further, with appropriate adjustments, SRI ideas and methods can be utilized to produce a variety of other important crops such as wheat, finger millet, sugarcane, some legumes and even some vegetables. This experience with a variety of crops in addition to rice, across a wide range of countries, indicates that there are ways to make the relationship between agricultural production and environmental conservation positive-sum.

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