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RESEARCH ARTICLE

EFFECT OF CARBON BALANCE ON COMPETITIVENESS AND COMPARATIVE ADVANTAGE OF RICE PRODUCTION SYSTEMS IN NIGERIA, WEST AFRICA

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Abstract

Rice imports play a significant role in satisfying the high demand for rice in most West African countries including Nigeria. This has made these countries focus more on increased rice production. Climate change is a major issue for the sustainable development goals hence greenhouse gas emissions from rice production systems are of great concern. The study employed the Policy Analysis Matrix (PAM) to assess the effect of carbon balance on the competitiveness and comparative advantage of rice production systems in the northern region of Nigeria. The Ex-Ante Carbon Balance Tool was used to assess the carbon balance of rice production systems. Results of the analysis implied all production systems are competitive and have comparative advantage except for the irrigation system. Incorporation of carbon balance in the economic analysis reduces the comparative advantage of irrigated rice production system further. The study also revealed that the irrigation system benefits more from Government's policies. It was observed that investing in technologies that would increase productivity will not guarantee low carbon emission hence the need to also go for climate-smart agriculture. This would advance climate-friendly rice production leading to a reduction in greenhouse gas emissions and steady rice supply. This will in turn lessen the necessity for distorting policies.

Keywords: Competitiveness, Comparative Advantage, Carbon-balance, Policy Effects, Rice Production Systems

INTRODUCTION

In recent years, the Federal Government of Nigeria has shifted its attention not only to increased food production, but on rice as one of the priority crops in its effort to achieve domestic food security and boost export earnings. Over a couple of decades, rice has transcended into a major staple in Nigeria. Changes in lifestyle and employment patterns, in addition to population growth, have significantly contributed to broadening the gap between rice supply and demand in Nigeria (Codjo *et al*. 2016). Even though rice production in Nigeria is steadily increasing there are concerns as to the country's ability to match the exponential growth in demand. Using the production-consumption ratio as a pointer to self-reliance in rice production, Van Oort *et al*. (2015), observed that with the existing pattern in productivity, consumption, and population growth in Nigeria, land area devoted to rice cultivation would need to increase by more than hundred percent in 2025 to achieve self-sufficiency. The existence of large difference between possible and actual yields in Nigeria is an indication that rice intensification and double cropping in irrigated systems is a major option to increased productivity and output. However, intensive rice farming systems further deteriorate soil productivity and carbon balance of the ecosystem by increasing carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emission (Yao *et al*. 2014; Ali *et al*. 2019).

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Agricultural production is responsible for about half of methane emissions globally, usually from cattle, rice plantations, wetlands, and fertilizer application (Smith, *et al*. 2007). The significant amount of global emissions from agriculture and changes in land use is expected to further increase in the future through mainly the projected increase in population, growing use of nitrogen fertilizers and the augmenting consumption of meat and dairy products (Food and Agriculture Organisation (FAO), 2013). Nigeria's First Biennial Update Report (BUR1) shows that in 2015, overall releases from agriculture, forestry, and other land use (AFOLU) were key sources of GHG emissions (66.9percent). According to FAO (2017), the potential for curbing GHG emission in agriculture is high and this can substantially be carried out in developing countries. The economic mitigation potential for various prices per tonne of CO_2-e was estimated at 1,500-1,600 MtCO_2-e/year (20 US$), 2,500-2,700 Mt$CO_2$-e/year (50 US$), and 4,000-4,300 MtCO_2-e/year (100 US$). This makes agricultural mitigation an economical strategy compared to non-agriculture options. Specifically, crop and livestock abatement options were identified as the most economical areas (FAO, 2017).

One of the principles on which the basis for estimating projects' development impact is that a project is assumed to boost development if its benefits are more than the costs. These include both tangible benefits that can be estimated in financial terms and externalities that may be difficult to monetize but are important project outcomes (World Bank, 2013). Therefore, to be considered efficient, rice production systems must have high yield and low environmental impacts such as low GHG emissions and its accompanying Global Warming Potential (GWP) (Boateng *et al*. 2017).

Several studies have been carried out using the PAM to assess competitiveness and comparative advantage of agricultural systems. However, there is a dearth of literature on the inclusion of GHG as a cost to the society. Increased rice production is expected to have a bearing on the natural resource environment therefore, in addition to tackling problems associated with competitiveness and efficiency, policymakers must take account of this impact in order to estimate the true social cost of the systems. Consequently, the focus of this research is to determine the competitiveness and comparative advantage of rice production systems while considering the consequential increase in greenhouse gas emissions due to increased rice production.

MATERIALS AND METHODS

The study area

The study was done in Kebbi State, Northwest Nigeria. The total land area available for cultivation in the state consists of 320,000 hectares (ha) of upland and 170,000 ha of low land (fadama), with high probability of surface and shallow ground water to support irrigation activities (Kebbi State Government (KSG), 2017). The vastness of agricultural land creates an opportunity for agricultural activities including rice production throughout the year. Kebbi state occupies a strategic position in Nigeria's drive for increased rice production. The State is one of the major producers of rice in Nigeria. Majority of rice production ecologies found in the country abound in the state. Activities of the Federal and State Governments in supporting rice production in the State have brought a boost to rice production in the area. Having common borders with the republics of Benin and Niger, rice production systems in the area are vulnerable to incidence of cross border smuggling and proliferation of imported rice. In addition, weak enforcement of agro-input subsidies has also been identified to be central in undermining the efforts of the Government in improving competitiveness of the locally produced rice with imports. With the launching of the Presidential Anchor Borrowers Program (ABP) for rice farmers in 2016, The state government has committed to making agriculture an all-year-round occupation. Hence, focus has been centred on the restoration of current irrigation systems and the building of new dams and irrigation schemes (KSG, 2017, Central Bank of Nigeria (CBN), 2016) to further boost rice production.

Sampling Methods and Data Collection

Multistage sampling technique was used in the selection of respondents. Sample frame for small scale rice farmers in the selected LGAs were obtained from Kebbi State Rice Farmers Association of Nigeria (RIFAN). The sample size was determined proportionate to the population using Yamane's formula. A total of 375 respondents were randomly selected for the study. Average values were used to estimate the variables for the analysis.

Estimating the value of carbon balance of rice production systems

The Ex-Ante Carbon Balance Tool (EX-ACT) was utilized to estimate externality (emissions of CO_2, N_2O and CH_4) due to rice production systems. The EX-ACT is a land-based method of accounting, built by FAO for assessing changes in carbon stock (that is sinks or emissions of CO_2) and GHG emissions per unit of land, expressed in metric tonnes of CO_2 equivalent per hectare per year. The carbon balance of each of the production systems was valued using the shadow price of carbon as recommended by the World Bank (2017). A range of US$37-75 per ton of CO_2e in 2017 was recommended, rising to US$50-100 per ton of CO_2e by 2030. To incorporate environmental externality into the economic analysis of the rice production systems, the shadow price of carbon (US$/ t$CO_2$e) was multiplied by the estimated annual GHG emissions (tCO_2e/ha).

The Policy Analysis Matrix (PAM) Framework

Table 1 is the framework of the PAM. The PAM is a mathematical concept advanced by Monke and Pearson (1989) for estimating the efficiency of inputs used in production, the comparative advantage of the production system, and the extent of interventions by the Government (Nelson and Panggabean, 1991).

The PAM is derived from two accounting identities, the profitability identity, expressed as revenues less costs, and the divergences' identity which is expressed as the variance between existing prices and prices that would exist without distortions. By completing the PAM for an agricultural system, one can easily determine the degree of transfers due to the different interventions working on the system and the system's underlying economic efficiency.

Private profits and private cost ratios (PCR) are the main indicators of profitability and competitive advantage. These are attained from the top row of the PAM. The value of private profit expressed as revenues less costs (D=A-B-C), suggests the competitiveness the system, under the current technologies, values of output, input costs, and policy transfers. Since the cost of capital, which is pre-tax return that farmers need to sustain their enterprise, is part of domestic costs, profits are 'excess-profits-above-normal' returns to farmers. Negative profits (D < 0), indicate farmers are incurring losses (subnormal returns) and thus are expected to abandon the activity unless profits increase to at least a normal level (where D = 0) or higher. On the other hand, positive private profits (D > 0) indicate 'supernormal returns' and should encourage increased investment in the system, unless there are challenges, or alternative crops that are more competitive. The private cost ratio (PCR) shows the degree to which a system can cover for domestic factors and

Table 1: The Policy Analysis Matrix (PAM) framework

	Revenues	Costs		Profit
		Tradable Inputs	Domestic Factors	
Financial Prices	**A**	**B**	**C**	**D**
Economic Prices	**E**	**F**	**G**	**H**
Divergences	**I**	**J**	**K**	**L**

Source: Monke & Pearson, 1989

Note: Financial profits, D = A - B - C. Economic profits, H = E - F – G, 1nput transfers, J = B - F. Output transfers, I = A - E. Factor transfers, K = C - G. Net transfers, L = I - J – K = D - H.

remain competitive. It is the ratio of costs of domestic factors to value added in market prices (PCR=C/(A-B)). Rational farmers will expect to earn excess profits (D > 0), which is achievable if domestic factor costs (C) are less than value added in private prices (A - B). Thus, a system remains competitive as long as the value of the PCR is below one.

PAM indicators for degree of comparative advantage include economic profit, domestic resource cost (DRC) ratio and social cost benefit (SCB) ratio. Economic profit is revenues less costs, assessed in economic prices (H=E-(F-G). A positive value of H suggests that production is increasing national income, while a negative value implies otherwise, hence it would be more beneficial for the country to engage in something else. The DRC ratio expressed as DRC=G/(E-F), on the other hand, relates the opportunity cost of factors used with the value created in border prices (Greenaway and Milner, 1993). The DRC ratio is considered a good measure of comparative advantage. With its focus on domestic factor costs, DRC emphasises the Heckscher-Ohlin concept of comparative advantage which stipulates that countries are inclined towards exporting products that use cheap and abundant domestic factors while importing those that use resources that are scarce. The DRC ratio has been generally used in third-world countries to measure comparative advantage and to direct policy improvements (Masters and Winter-Nelson, 1995). A positive DRC value less than 1 (0 < DRC < 1) implies the amount of foreign exchange saved is higher than domestic factors used in the production process thereby depicting comparative advantage. A value greater than 1 (DRC > 1) implies otherwise, that is a comparative disadvantage. Despite its usefulness in estimating the comparative advantage of production systems, the DRC ratio has been shown to be partial to projects that rely more on domestic resources, and that SCB ratio is a better measure of comparative advantage (Masters and Winter-Nelson 1995; Kannapiran and Fleming, 1999; Fang and Beghin, 2000, kassali and Jimoh, 2018). The SCB ratio expressed as SCB= (F+G)/E, makes use of the same data as the DRC with the added advantage of not distorting profitability rankings since it is not affected by the categories of inputs.

The protection indicators commonly used in the PAM are the Nominal Protection Coefficient (NPC), the Effective Protection Coefficient (EPC), and the Profitability Coefficient (PC). Various studies have indicated the importance of these indicators in assessing the effects and impact of policies, on agricultural production (Yao, 1993; Masters & Winter-Nelson 1995; Ali and Khan, 2012; Mantau *et al*. 2019). The NPC utilizes an input-output approach. The NPC for output indicates the percentage by which policies are raising or lowering the financial price of output compared to the world price (NPCO=A/E). An NPCO that is below one (NPCO < 1) indicates production is taxed. Whereas an NPCO greater than one (NPCO > 1) means that the system is favoured by policies. The NPC for Input (NPCI = B/F) on the other hand, indicates the percentage by which agricultural policies are increasing or decreasing the market prices of inputs compared to the world prices. An NPCI higher than one (NPCI > 1) indicates that domestic costs of inputs are higher than international prices, hence the system is overtaxed by policy. An NPCI below one (NPCI < 1) indicates otherwise, that is market prices are lower than international prices therefore the system is backed by policy. The EPC compares value added in private prices with value added in international prices (EPC=(A-B)/(E-F). The effective protection coefficient is more robust in measuring incentives to farmers. It takes account of different distortions due to interactions amid different strategies in determining degree of Government protection (Mucavele, 2000). An EPC more than one (EPC > 1) implies producers are favoured, while an EPC less than one (EPC < 1) indicates that producers are overtaxed. The EPC is suitable for comparing products that use dissimilar levels of input (Masters, 2003). However, it does not consider transfer effects of policies affecting factor markets hence the concept of profitability coefficient (PC) was proffered (Monke & Pearson 1989; Touré *et al*. 1999).

The PC is estimated as the ratio of net revenue at market prices to net revenue at social prices (PC=D/H). It provides an estimate of the incentive effects of all policies and thus represents net policy transfer (Monke & Pearson 1989). A PC value less than one (PC < 1) indicates the presence of distorting policy or market failure (net disincentives to production), whereas a PC value greater than one (PC > 1) suggests subsidy to the system (incentives to production).

RESULTS AND DISCUSSION

Competitiveness of rice production systems

The result in table 2 indicates that all production systems are profitable given the positive values of their private profits. This implies all systems are competitive under the existing conditions (Nelson and Panggabean, 1991; Masters and Winter-Nelson 1995).

The irrigated rice production system was the most profitable with a value of US$989/ha, followed by the upland rain fed system with US$940/ha. The least profitable was the lowland rain fed system with a profit of US$919/ha. A previous study by Ugochukwu and Ezedinma (2011), also implied that lowland; upland and double-rice-cropping systems in south-eastern Nigeria were financially competitive. Studies carried out in other parts of the country including Kebbi State also confirm the positive private profitability of rice production systems in the country (Liverpool *et al*. 2009; Ogbe *et al*. 2011, Ammani *et al*. 2015; Gona and Ishaya, 2019). The positive values of the private profit for all the production systems indicate supernormal returns. It is thus expected that farmers may be inclined to increase investment in the production systems, unless they are restricted by availability of farming area, or alternative crops are more privately profitable.

Because the different production systems do not use same units of inputs due to topography, soil type and availability of water, direct appraisal of the data for private profits may not be adequate (Masters and Winter-Nelson 1995). These peculiarities are adjusted for through the PCR. The PCR for all the production systems are less than one. This indicates that spending on domestic factors is less than value added. This is an indication that all production systems have competitive advantage in rice production. Unlike with the private profits, the lowland rain fed system had the least PCR of 0.36 indicating it is the most competitive. This is followed by the irrigation system with a value of 0.38. The upland rain fed system has a PCR of 0.40 indicating it is the least competitive. This agrees with the findings of Ogbe *et al*. (2011), which affirmed a strong competitiveness of the irrigated rice and upland rice systems at the farm level. Ammani *et al*. (2015) also reported a PCR value of 0.40 for rice production in Kaduna State.

Comparative advantage of rice production systems

The results in Table 3 show that social profits for upland and lowland production systems were positive while the irrigation system yielded a negative value. This indicates that for the upland and lowland rain fed systems, rice production is economically efficient. The most efficient is the lowland rainfed system with an economic profit of US$109 followed by the upland rainfed system with an economic profit of US$101.

Several studies have also observed positive social profits for rice farmers in other parts of

Table 2: PAM Indicators of Competitiveness of Rice Production Systems

Production Systems	Private profits (PP) US$	Private Cost Ratio (PCR)
Upland rain-fed	940	0.40
Lowland rain-fed	919	0.36
Irrigation	989	0.38

Source: Researcher's computation from field survey, 2018

Table 3: PAM Indicators of Comparative Advantage of Rice Production Systems

Production Systems	Social Profit (US$)	Domestic Resource Cost	Social Cost-Benefit Ratio
Upland rain-fed	101	0.89	0.92
lowland rain-fed	109	0.87	0.90
Irrigation	-102	1.13	1.07

Source: Researcher's computation from field survey, 2018

the country (Liverpool *et al*. 2009; Ogbe *et al*. 2011; Ammani *et al*. 2015). In case of the irrigation system, the negative value of US$-102 suggests that economically, the system is inefficient. The value of the DRC is greater than one (1.13), implying the country has no comparative advantage in rice production in this system. That is, it costs more than one unit of domestic resource to create an extra unit of foreign exchange from rice production. Hence, it is economically cheaper to import rice than to produce it locally using the irrigation system. This could be due to the fact that irrigated rice systems make use of more tradable inputs than the other systems. In addition to the costs incurred in the other production systems, costs such as boreholes and water pumps were incurred in the irrigated rice systems. Another cost peculiar to the system was fuel which covered about 10% of the variable cost of production. While water pumps and fuel were regarded as tradable in estimating their economic costs, boreholes were regarded as non-tradable. This also implies, production cost exceeds the cost of imports consequently, the system would need government support through distorting policies to survive. Kikuchi *et al*. (2016) attributed lack of comparative advantage in rice irrigation systems to cost of irrigation facilities. It was observed that once these costs are treated as sunk costs, irrigated rice cultivation becomes internationally competitive. Akande (2002) also found mechanized gravity-irrigated rice systems not internationally competitive in any region of Nigeria.

The values of the DRC are less than 1 for upland and lowland rain fed systems. This indicates that the country possesses comparative advantage in rice production in these systems. In other words, it costs less than a unit of domestic factors to create an extra unit of foreign exchange from rice production. Consequently, it is better for the country to produce rice using these systems than to import it. The lowland rain fed system has the most comparative advantage with a value of 0.87 followed by the upland rain fed system with a value of 0.89.

The value of the SCB ratio confirms that the lowland rain fed system has the most comparative advantage with a ratio of 0.90. This implies lowland rice producers would generate about 10 percent profit from the cultivation of one hectare of land. This is followed by the upland rain fed with the SCB ratio of 0.92. As is the case with the DCR ratio, the irrigation system had no comparative advantage with SCB values of 1.07. This confirms the results obtained from the DCR analysis.

Policy effects on rice production systems

Table 4 is the PAM indicators of the effects of policy on rice production systems. The NPCO value of 1.55 indicates that rice producers are protected while consumers are taxed. Price is heavily affected by government policies which are raising the domestic market price of rice to a level 55 percent higher than the corresponding international reference prices. This is an incentive to producers since policies are making them realize higher revenue than they would have received in the absence of these policies. Ammani *et al*. (2015) also reported an NPCO value of 1.53 for rice production in Kaduna State. The values of the NPCI for all production systems except irrigation system is above one. This indicates that domestic prices of inputs are also greater than their economic or world prices. This is a discouragement to farmers

Table 4: PAM indicators for Policy Effects

Production Systems	NPCO	NPCI	EPC	PC
Upland rain-fed	1.55	1.10	1.71	9.28
lowland rain-fed	1.55	1.16	1.66	8.44
Irrigation	1.55	0.89	2.03	-9.72

Source: Researcher's computation from field survey, 2018

since they are paying more for inputs than their true economic cost.

The higher prices of inputs may also be partly attributed to the high inflation rate in the country due to several of the agricultural policies being implemented. In the case of the irrigation system, the NPCI is 0.85 implying prices of inputs are 15% less than the world prices. This could be ascribed to the irrigation system using more tradable inputs such as fuel and irrigation equipment than the other systems of rice production. An NPCI value of 0.94 was also reported for rice production in Kaduna State (Ammani *et al.* 2015).

The EPCs for all production systems are greater than one implying the negative effect of policy on inputs is being offset by the positive effect on outputs. This implies that government policies are providing net positive incentives to rice farmers in the study area. This could be due to input subsidies or trade restrictions that may push up the price of locally produced rice. The irrigation system enjoyed the highest protection with an EPC of 2.03. The production system with the least protection is the lowland rain fed with an EPC of 1.66. The upland rain fed system had an EPC of 1.71.

PC is a more robust measure of net transfer since it provides an indication of the net effect of policies as well as those affecting factor markets. The practicality of the PC is however constrained when either economic or market or profits are negative (as is the case with the irrigation system) considering signs of both entries would have to be uniform to permit logical interpretation. Table 5 indicates that the Upland rain fed system has a profitability coefficient of 9.28. This implies private profits are more than nine times greater than they would have been without policy transfers.

The PAM and Carbon Footprint of Production Systems

Carbon Balance of Rice Production Systems

The result of the Ex-Ante Carbon Balance Tool as shown in table 5 indicates that the least net emission of 0.04 tCO_2eq is observed by the lowland rain fed rice system. The upland rainfed rice system has a net GHG emission of 0.05 t CO_2eq while the irrigation system has the highest net emission of 2.39 tCO_2eq. This is primarily due to the higher use of fertilizer compared to the other systems and also the use of fuel. The positive values of the net GHG emission indicate that all production systems add more CO_2 equivalent into the atmosphere than it is sequestered. Consequently, the values of the net GHG emission is treated as a cost to the society rather than benefit.

According to the World Bank (2013), applications of economic analysis are likely to be more complex than they were several decades ago due to changing systems and methodologies. It was observed that the obvious link between a project's economic analysis and the development objectives calls for using approaches and methodologies in line with the project, sector, or country conditions. There may also be need for alternative approaches. In line with this observation, the study tries to estimate the effect of carbon footprint on comparative advantage of the production systems. Carbon footprint is an economic cost to the society; hence it has no effect on the competitiveness of the production systems at least in the short run. The effect of carbon footprint on DRC ratio, and the SCB ratio of the production

Table 5: Carbon Balance of rice production systems expressed in tCO_2eq

Production Systems	Total Emission	Total emission/ha	Total emission/ha/year
Upland Rainfed	37,465.96	0.97	0.05
Lowland Rainfed	29,738.30	0.89	0.04
Irrigation	1,980,927.24	48.47	2.42

Source: Ex-Ante Carbon-balance Tool

systems were therefore considered. The first scenario involved the ratios without the carbon footprint, while the ratios with low and high value of carbon made up the second and third scenarios. This is necessary considering the High-Level Commission on Carbon Prices recommends that projects' economic analyses are carried out using a low and high estimate of the carbon price (FAO, 2017). The commission finds this consistent with the presence of uncertainty linked to the volatility of future global socioeconomic and technological trends.

Figure 1 shows the responsiveness of the DRC of the production systems to the different values of the shadow price of CO_2 emitted by the respective systems.

As indicated in the figure, the incorporation of the carbon footprint of the production systems had no effect on the DRC of the upland rain fed production system. A one percent increase in DCR was observed in the lowland rain fed system. The DRC value of the irrigation system on the other hand was affected by the carbon footprint. This could be associated with the high carbon emission associated with the production system. Use of low value of CO_2 for the irrigation system increased the values of the DRC by 12 percent while using the high estimate, the DRC value increased by about 30 percent. This implies that incorporating carbon footprint in the PAM analysis exacerbates the lack of comparative advantage of the irrigation system. The same effect is seen with the SCB ratios of all the production systems indicated in figure 2.

The result of the analysis indicates that the carbon footprint had less than 1% impact on the SCB ratio of the upland, and lowland rainfed systems. In the case of the irrigation system, changes of about 6 percent for low estimate and 12 percent for high estimates of carbon footprint were observed. This confirms that the inclusion of the carbon footprint further makes the irrigation system devoid of comparative advantage as revealed by the DRC analysis.

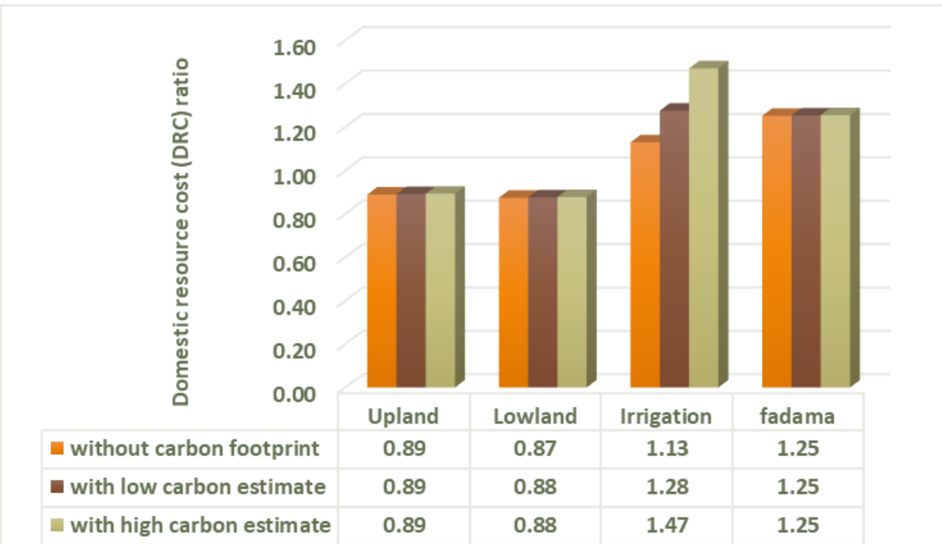

Figure 1: Values of DRC with and without Carbon Footprint

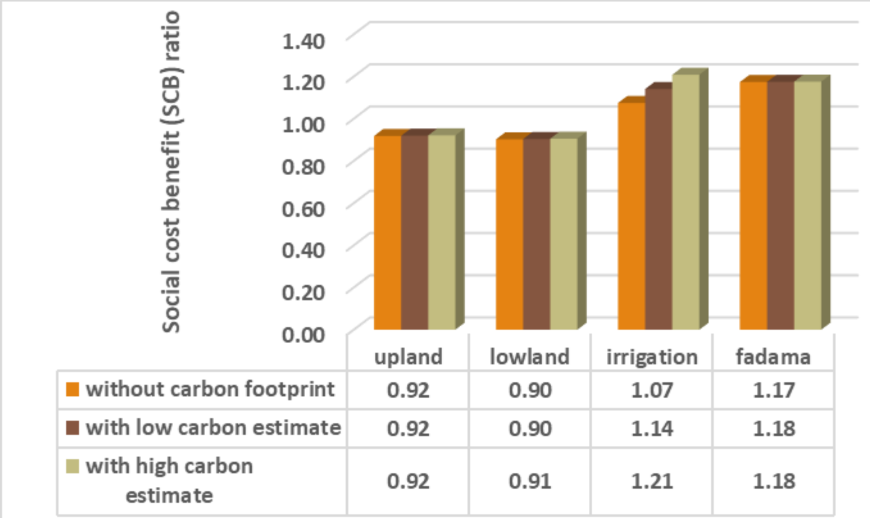

Figure 2: Values of SCB with and without Carbon Footprint

CONCLUSION

The study concludes that rice farming is a profitable venture under the prevailing policy environment. The profitability of the production systems under current market prices faced by farmers in the study area may be driven by their high productivities and distorting policies. Social profits for upland and lowland production systems were positive implying systems are efficient economically. That is the country uses resources that are scarce efficiently and currently has comparative advantage in rice production under the upland and lowland rain fed systems. The irrigation system on the other hand is found to be economically inefficient suggesting that economically, the sector is exploiting factors which could be used more efficiently in alternative projects or sectors of the economy. This implies, under this production systems, production cost surpasses the cost of imports consequently, the system would need government support through distorting policies to survive. The incorporation of the carbon footprint of the production systems had no effect on the DRC of the upland rain fed production system. A one percent increase in the value of the DRC was observed in the lowland rain fed system while incorporating carbon footprint in the PAM analysis exacerbates the lack of comparative advantage of the irrigation system by about 21 percent (based on the values of the DRC). The result revealed that all production systems are effectively subsidized by the existing government policies. This enables the farmers to obtain higher financial return despite the high prices of inputs. Hence Government is achieving its objective of providing protection to rice farmers through distorting policies to encourage local production of rice while keeping the systems competitive.

Sustainable rice production is seen to increase yield and resource use efficiency, through its dependence on yield potential, soil quality and smart agriculture (Tilman *et al.* 2011; Cassman, 1999). This is particularly vital in countries like Nigeria, where large yield gaps between rice production and supply remain (Beza *et al.* 2017, Laborte *et al.* 2012). Therefore, Government's strategies to encourage rice intensification and increase supply response through the expansion of irrigation systems need to be carefully designed bearing in mind the environmental cost to the society so that negative environmental externalities are minimized. Farmers should be targeted in campaigns for climate-smart agriculture and the use of improved practices that would reduce the effect of conventional agriculture practices on the environment such as adhering to the recommended doses of agro-chemicals, site-specific soil-crop fertilizer use and solar powered irrigation technologies. With the observed positive values of the private profits even without the use of subsidized inputs, the challenge facing the government may be in the determination of the optimal level of protection needed to sustain the systems and committing to a sound exit strategy to avoid a budgetary crisis on account of increasing unsustainable support of the industry.

AUTHOR CONTRIBUTION

SBA and CAAA designed the study. SBA drafted the questionnaire. CAAA, TL and YES reviewed the questionnaire. SBA and CAAA analyzed the data. SBA wrote the paper with input from all authors. All authors discussed the results. TL and YES reviewed the manuscript.

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