Paper/Poster Title	Ex-post impact of integrated rice-fish farming system technology on welfare of small-scale farmers in Liberia: An application of marginal treatment effect model

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Abstract	*200 words max*

In this study, we analyze the heterogeneity in the impacts of integrated rice-fish farming system technology (IRFFST) on welfare indicators such as yield, production, food security, nutrition security, quantity of fish consumption and poverty reduction in Liberia. We employ the marginal treatment effects (MTE) approach to estimate the treatment effects heterogeneity and policy-relevant treatment effects (PRTE) on cross-sectional survey data of 967 rice farmers. The findings show substantial heterogeneity in benefits from adoption of IRFFST with respect to both observed and unobserved household characteristics. Among the determinants of adoption, the key determinants are access to credit, access to irrigation in lowland, farm size and access to extension services. The empirical results show that adoption of IRFFST significantly reduces household food insecurity and increases rice yield, production and quantity of fish consumed in the household. On average, a random farmer selected among the rice farmers had their yield and food consumption score increase by 648 kg and 8.28 points, respectively. Overall, the article provides evidence that promoting IRFFST is important to improve welfare of rural people especially for marginalized poor indigenous small scale rural farm households in Liberia. But necessary interventions are needed to overcome the inhibiting factors for more widespread adoption of this promising technology considered as promising model for adapting to climate change and sustainable agriculture in developing countries.

Keywords	Integrated Rice-Fish farming System Technology, adoption, double-hurdle model, impact, marginal treatment effects, household welfare, Liberia
JEL Code	Q13, Q18, C93 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	*100 – 250 words*

Agriculture is the mainstay of the economy and is also a key sector for human development and economic growth in Liberia. According to the World Bank (2019), over 75 percent of the population relies on agriculture for their livelihood. The sector contributes 25-35 percent to Liberia's GDP. Rice is rapidly gaining in importance as a staple food and is now one of the largest sources of food energy in SSA. It represents the basic food for more than 750 million persons in SSA (USDA, 2020). Rice consumption is growing faster in Africa and particularly West Africa than any part of the World. In West Africa, about 310 million people derive about 20% of their daily calories from rice. However, rice demand in this region is growing faster than local supply, leading to substantial rice imports and dependence on international rice prices. As farmers intensify production through increased use of chemical inputs, concerns about the negative effects of such practices on human health and the environment are growing.

Therefore, improved crop management practices that lead to productivity gains with minimum adverse effects on the quality of the natural resource base are needed to reduce the importation bills and to achieve Sustainable Development Goals (SDG) in Liberia. Integrated rice- fish culture, an age-old farming system, is such a farming system technology which could produce rice (source of carbohydrate) and fish (source of high-quality animal protein) sustainably at a time by optimizing scarce resource use through complementary use of land and water (Frei and Becker, 2005; Edward et al., 1988). The general objective of this study is to assess the adoption and impacts of integrated rice-fish farming system technology on welfare of small-scale farmers in Liberia.

Methodology   *100 – 250 words*

The study was conducted in five counties (regions) of Liberia: Margibi, Maryland, Gbarpolu, River Gee and Grand Gedeh. In total, 967 rice farmers including 446 rice farmers beneficiaries and 521 rice farmers non-beneficiaries of DeSIRA were randomly selected and interviewed. We employ the marginal treatment effects (MTE) approach to estimate the treatment effects heterogeneity and policy-relevant treatment effects (PRTE) on cross-sectional survey data of 967 rice farmers. MTE allows us to estimate the treatment effect heterogeneities across households and simulate the effects of policy changes on outcomes such as yield, income, food security and poverty. we use the "mtefe" command of STATA to estimate the parametric normal approach of the marginal treatment affect model.

Results   *100 – 250 words*

Mean difference tests showed that the hypothesis of no difference between adopters and nonadopters of the IRFFS is rejected for most characteristics. These results underscored the presence of selection into adoption, and heterogeneity between adopters and nonadopters must be considered in the impact assessment of the IRFFS technology. Among the determinants of adoption, the key determinants are access to credit, irrigation, farm size, being train on IRFFS and access to extension services. Results suggest that more efforts (like access to credit, irrigation, information, and land) are needed to uplift resource-poor farmers to increase the probability that they will adopt the IRFFS technology to a great extent. The empirical results show that adoption of IRFFST significantly reduces household food insecurity and increases rice yield, production and quantity of fish consumed in the household. On average, a random farmer selected among the rice farmers had their yield and food consumption score increase by 648 kg and 8.28 points, respectively. Overall, the article provides evidence that promoting IRFFST is important to improve welfare of rural people especially for marginalized poor indigenous small scale rural farm households in Liberia.

Discussion and Conclusion   *100 – 250 words*

This study was conducted as part of the implementation of the "Development of Smart Innovation through Research in Agriculture (DeSIRA) initiative" in Liberia. DeSIRA initiative mainly focus on the promotion and dissemination of Rice-fish farming systems in Liberia. The general objective was to assess the determinants of adoption and welfare impact of IRFFST in Liberia. Improving poverty, food and nutrition security situations are Liberia 's and many African countries policy priorities. In this respect, integrated rice- fish farming system technology is expected to play an important role by supplying rice, fish and vegetables together in a sustainably way in Liberia. Overall, the article provides evidence that promoting IRFFST is important to improve welfare of rural people especially for marginalized poor indigenous small scale rural farm households in Liberia. But necessary interventions are needed to overcome the inhibiting factors for more widespread adoption of this promising technology considered as promising model for adapting to climate change and sustainable agriculture in developing countries.