CHEMICAL FERTILIZER IMPORTS AND THE ENVIRONMENT: EVIDENCE-BASED APPROACH FOR A GREEN ECONOMY ACCOUNTING FOR THE TRADEOFF

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Abstract

The direct and indirect impact of high-input use agriculture- popularised by the Green Revolution- on the environment is the major thrust of this perspective. The paper discusses an integrated approach to minimise the negative impacts, accounting for the proposed ban of synthetic fertilizers and the tradeoff between the environment and productivity resulting from such a ban.

Noteworthy stylised facts of the discussion are threefold. First, the Green Revolution reduced the growth of extensive expansion of agricultural lands via intensification, which subdued the pressure on forest cover. Additionally, productivity increase releases marginal lands for vital ecological services such as pollinator habitats. Second, synthetic fertilizer resulted in higher productivity in the agriculture sector, increasing the GDP and facilitating structural transformation. Given that a quarter of the workforce is in the agriculture sector, gradual movement of the labor force to the industrial sector is vital, while the agriculture sector workforce become self-reliant in facing environmental and climatic events. Thus, continuous investment in agricultural productivity growth should be a priority to create fiscal space for the investments in meaningful green initiatives and reduce the vulnerability of the rural poor. Third, evidence-based solutions such as site-specific fertilizer recommendations, soil testing, and discouraging overuse of nitrogenous fertilizer through tariffs should be practised to mitigate the adverse environmental impact of synthetic fertilizer, especially nitrogen fertilizer.

Complete removal of the subsidy may generate overreaching welfare and environmental ramifications, although it is widely suggested.

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"*Whoever makes two ears of corn, or two blades of grass, to grow upon a spot of ground where only one grew before would deserve better of mankind and do more essential service to his country than the whole race of politicians put together*."
Jonathan Swift in Gulliver's Travels[1]

INTRODUCTION

High-Yielding Varieties (HYVs) were adopted by farmers worldwide after the popularisation of the Green Revolution in the 1960s. Semi-dwarf rice and wheat that were highly responsive to Nitrogen, Phosphorous and Potassium fertilizers invaded the farmlands previously occupied by the taller, less fertilizer responsive, and low-yielding varieties. The dramatic transformation resulted in significantly higher agricultural productivity, positively affecting the per capita GDP of the countries in the developing world (Gollin et al., 2021). However, while the Green Revolution's impact on agriculture productivity and household welfare is well established, concerns remain about the environmental impact of the Green Revolution. Environmental pollution, notably soil and water contamination, biodiversity loss, and collateral harm on organisms due to high input usage, is a widely discussed negative aspect of the Green Revolution.

The environmental concerns lead to new movements that demand low input use agriculture systems, including organic agriculture, although high input use intensive agricultural systems still dominate the world agriculture. Sri Lanka's agricultural productivity drive in the 1968-69 period through the introduction of HYV varieties was successful when the above-average adoption rate of HYVs and the resulting agricultural productivity growth were considered. It is essential to mention that the Sri Lankan farmers rapidly adopted high-input agricultural practices as revealed by input usage data. Conversely, the development economics literature has documented the need for nudging in other countries to increase fertilizer application (Duflo et al., 2011; Duflo & Banerjee, 2011). Instead, in Sri Lanka, the successive governments allocated scarce public revenue for the fertilizer subsidy, which is blamed for the alleged overuse of synthetic fertilizer (Rodrigo & Abeysekera, 2015; Weerahewa et al., 2010, 2021). Fertilizer subsidy exerts pressure on the limited fiscal space of the government, and as most synthetic fertilizers and agrochemicals were imported, the import bill is a burden.[2] Moreover, the intensification of agriculture steadily demanded more inputs with alleged harmful impacts on soil, water sources, and human health, motivating debates on the negative externalities of the Green Revolution. The environmental concerns culminated in Sri Lanka with the

[1] Gollin et al. (2021) should deserve the credit for using this extract from the literature classic to creatively start their influential paper "Two Blades of Grass: The Impact of the Green Revolution."

[2] Sri Lanka spent 260 USD million to import fertilizer (HS chapter 31) in 2020 and nearly half of the expenditure was for mineral or chemical nitrogenous fertilizers.

ban on Nitrogen Phosphorus and Potassium (NPK) fertilizers and agrochemicals in 2021. Nevertheless, the legacy of the Green Revolution is most likely irreversible suddenly as we see widespread criticism on the decision both in technical and political realms.

Globally, the institutional attempts to produce HYVs took place in 1960, forming the International Rice Research Institute (IRRI) and the International Maize and Wheat Improvement Center (CIMMYT). The rice breeding began at the IRRI in 1962. The initial HYVs, after several rounds of selection, was released for national research programs. Local research institutes and university-based research programs tailored HYVs to local geographical and agronomics factors. Early literature documents the history and process of HYV breeding under the Green Revolution (Barker et al., 2014; Dalrymple, 1979, 1980, 1986). Against this backdrop, two crucial political and economic drivers behind the Green Revolution need to be noted. First, as the institutional nature of the research institutes involved in breeding was public, the HYVs were made freely available to the developing world. Second, the US funding- through Ford and Rockefeller foundations- was motivated by the threat of agrarian revolutions in Asia and Latin America, which due to the Cold War geopolitics, encouraged the US to support HYV breeding, especially rice (Gollin et al., 2021; Perkins, 1997). Thus, from the very beginning, the Green Revolution intended to increase household welfare. Indeed, the welfare impact in the counterfactual- no Green Revolution scenario- is estimated to be significantly higher (Gollin et al., 2021).

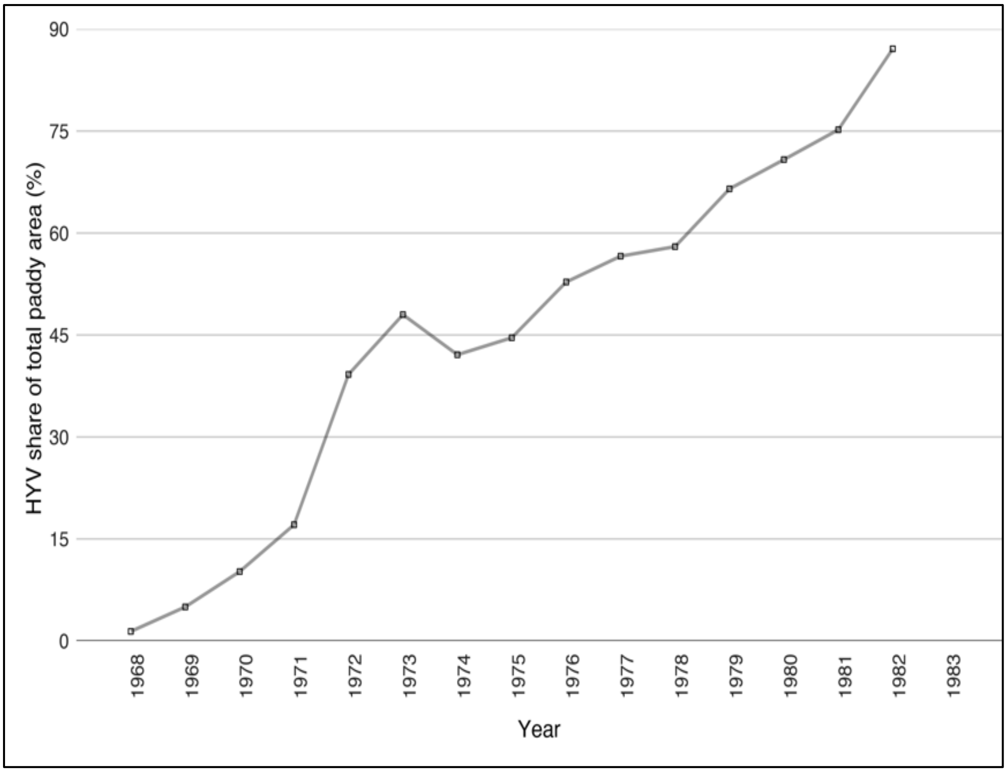
Rice varieties developed by the IRRI were introduced to Asian countries for adaptive breeding, where rice cultivation was integral to the rural economy. In the late 1960s, IRRI varieties were imported to Sri Lanka, but their primary role was as parents in Sri Lanka's breeding programs. In 1967, with the support of the Ford Foundation and an IRRI scientist, the Sri Lanka project for adaptive breeding of HYVs initiated[3] (Dalrymple, 1986). In the aftermath of the release of HYVs, they rapidly replaced traditional varieties. By 1982, 87.1 per cent of rice lands were occupied by the HYVs (Figure 1). By 2018, 98.8% of paddy lands used HYVs, and more than 94.0% of the land was under HYVs that has a duration of three and a half (75.2%) and three (19.1%) months (Department of Agriculture, 2019).

In this article, the author deliberates three questions and attempts to answer them using the existing knowledge. First, what the environmental benefits of high input use agriculture are, if any. I answer this question through three mechanisms that high input use agriculture may impact on the environment. These are the "Borlaug hypothesis" -which implies agriculture intensification led to reduced land use-, per capita GDP approach -where I argue that positive productivity shocks of intensive use of inputs increase opportunities for green financing-, and the equity approach-increased incomes of the economically marginal farmers will reduce conflicts with environment. Second,

[3] Old-improved varieties (H series) began to appear in 1957. The second phase introduced more lodging resistant new, improved varieties after 1970 (mostly the BG series).

what the costs of high input use are. I acknowledge that the mechanisms of the impact of input use-NPK fertilizer and agrochemicals- on the environment are primarily outside of the domain of the field of economics. Third, is about the way forward, i.e., how can we find an economically and environmentally optimum solution.

Figure 1: Evolution of the Early Adoption of HYVs in Sri Lanka

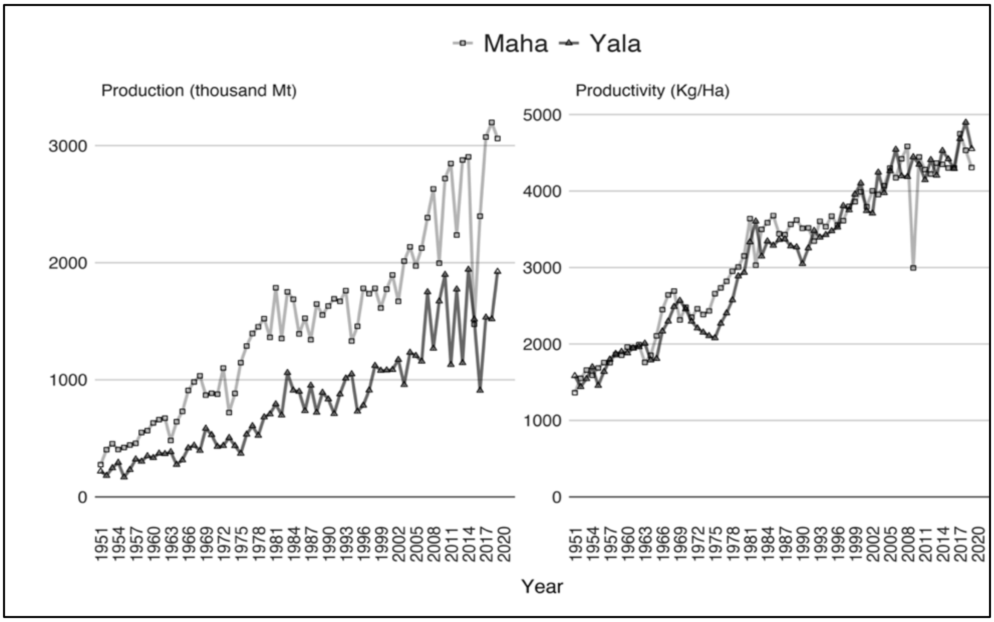


Source: Dalrymple (1986)

THE POSITIVE IMPACT OF HIGH-INPUT USE AGRICULTURE (GREEN REVOLUTION) ON THE ENVIRONMENT

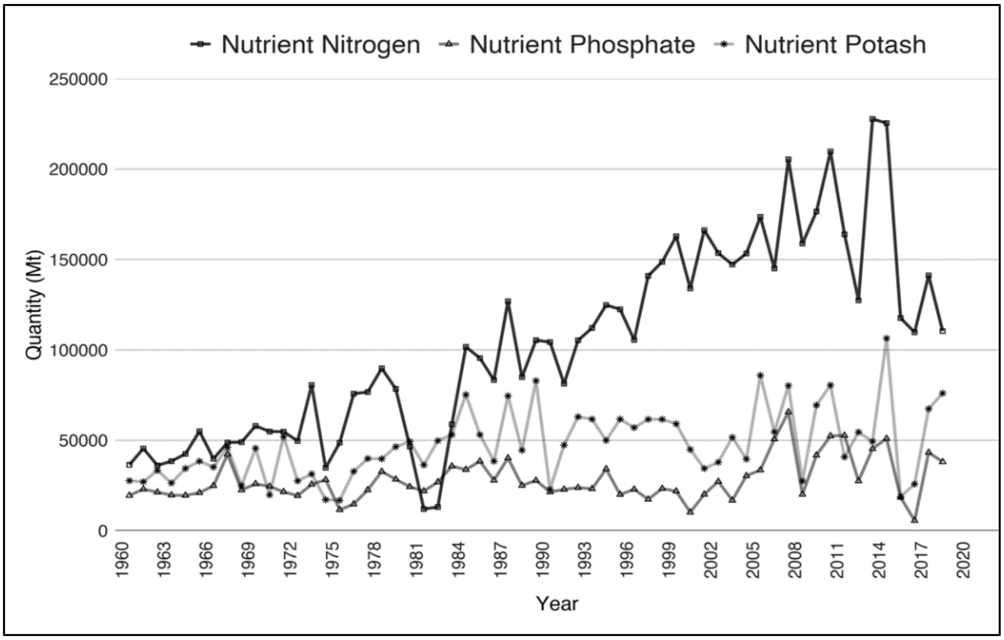
The high-input use significantly increased the productivity of rice cultivation, the staple cereal crop cultivated in Sri Lanka (Figure 2). The rice productivity increases with Nitrogen, Potassium, and Phosphorous fertilizer input per hectare (Figure 3). The high fertilizer input usage resulted from increased synthetic fertilizer use, especially Urea, a vital Nitrogen source. The fertilizer inputs and agrochemicals are imported to Sri Lanka (Figure 4 and Figure 5). However, the Green Revolution agriculture practices have increased domestic food production, assisted in achieving rice self-sufficiency, and contributed to the export-oriented agriculture sector. Moreover, the empirically estimated contribution of Green Revolution practices to the economy surpasses the input costs by manifolds (Gollin et al., 2021)

Figure 2: Evolution of Rice Production and Productivity in Sri Lanka 1951-2020



Source: Author's illustration using Paddy Statistics data from the Department of Census and Statistics, Sri Lanka

Figure 3: Annual Nutrients use by Primary Nutrient Type (Nitrogen (N), Phosphate (P_2O_5), and Potassium (K_2O))



Source: Author's illustration using data from FAOSTAT, Food and Agriculture Organisation

The impact of increased productivity on the environment, most notably to the forest cover, is an empirical question as it was argued that improvement in agriculture productivity would pull additional land into agriculture. On the other hand, Norman Borlaug-the unalienable scientist associated with Green Revolution- presented the "Borlaug hypothesis", which postulated that the improved varieties and higher agricultural productivity would lead to reduced pressure on land resources, higher production is achieved through intensification (Angelsen & Kaimowitz, 2001). Thus, if "Borlaug hypothesis" holds Green Revolution should reduce the extensive expansion of agricultural land use, reducing the pressure on forest cover.

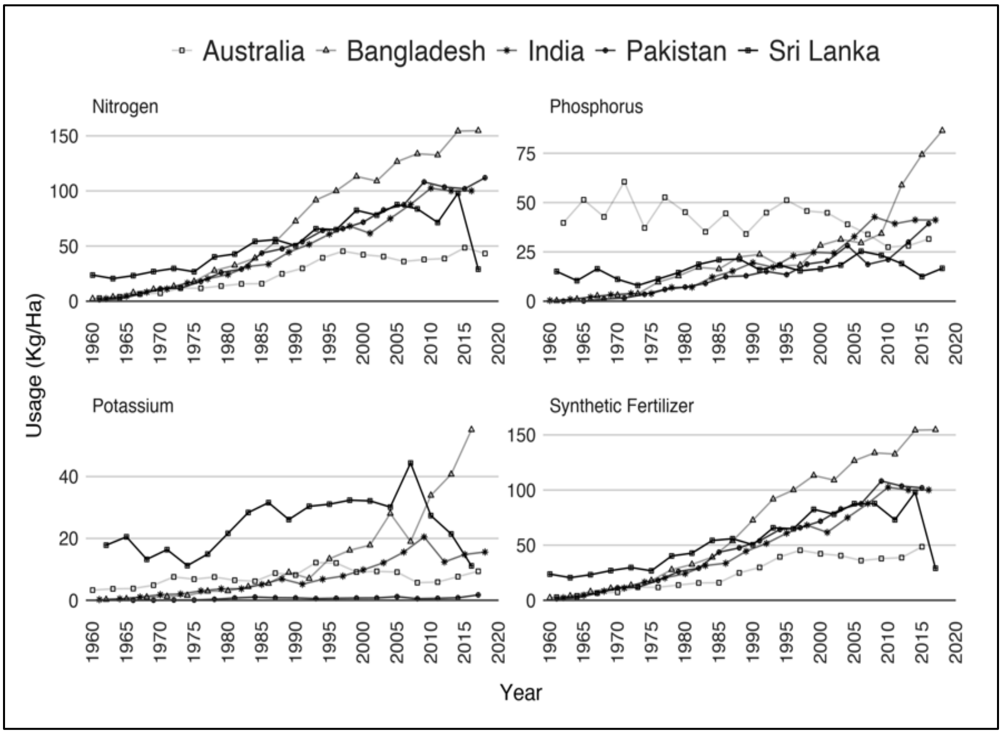
Testing a hypothesis for the impact of the Green Revolution on the extensive expansion of farmlands is challenging as there are various confounding factors. However, capitalising on the variation of the crop-specific release dates of HYVs for 90 developing countries, Gollin et al. (2021) have overcome the empirical challenge through a difference-in-differences research design.[4]. Notably, they found out evidence supporting the "Borlaug hypothesis" that an increase in agricultural productivity has a negative effect on the land area devoted to food crops. The productivity increase would have resulted in less growth of land allocation to food production than the counterfactual scenario. Gollin et al. (2021) documented higher yield gains-as much as 44%-for some crops. Other than the support for the "Borlaug hypothesis", Gollin et al. (2021) found out that Green Revolution had a robust impact on GDP per capita. By delaying the Green Revolution for ten years, the cumulative global loss of GDP would have been 83 USD trillion. Inevitably, the income loss for developing countries from such a hypothetical delay would have been significant.

The positive impact of high-input agriculture on the GDP of the developing indirectly strengthens the ability of those countries to mobilize resources to build a green economy. Although a green economy generates positive externalities like innovation that boost growth, it has a tradeoff as green efforts may affect productivity and growth (Hallegatte et al., 2012). The producers may have to replace technologies with greener ones. The governments will have to invest in green infrastructure. In Sri Lanka's context, higher growth is vital given the high debt ratio and the high interest rates to reduce the debt ratio or stabilize the latter in the long run. Thus, pushing the agricultural technology frontier outward to generate higher growth is imperative for a fiscally constrained country like Sri Lanka. One can question the relative importance of agriculture as early economic literature focuses more on industrial growth (Nurkse, 1953). However, a growing literature has produced sound theoretical models that illustrate the necessity of

[4] First, Gollin et al. (2021) estimated the crop-specific annual growth attributed to the Green Revolution. Then, the crop-specific estimates with country-specific shares of each crop in total agricultural production before the Green Revolution were used to construct a measure of the exogenous impact of the Green Revolution on aggregate yields for fixed allocations of land and labor. Note that the measure is a shift-share/Bartik instrument.

agricultural productivity growth to support the subsequent industrialisation (Gollin et al., 2007; Grabowski, 2013; Restuccia et al., 2008; Vollrath, 2011). Thus, Sri Lanka should continuously invest in pushing the technology frontier outward, as agriculture productivity increases GDP and facilitates structural transformation by releasing the labor force gradually[5] from agriculture. The outcome will be increased fiscal space for much-needed investments in transforming the economy into a green one.

Figure 4: Nutrients Usage Per Hectare by Selected Countries



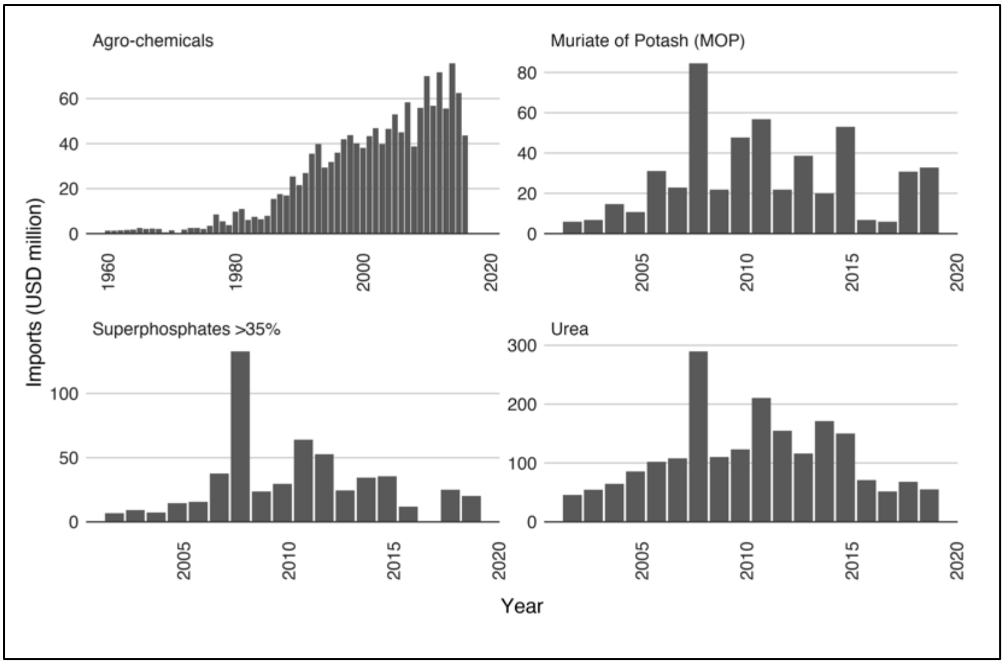
Source: Author's illustration using data from FAOSTAT, Food and Agriculture Organisation

The agricultural labor force in Sri Lanka, which was at around 25% in 2019, is disproportionate to the agriculture sector's contribution to GDP, which was just 7.5%. Mostly, rural agriculture workforce with informal labor force structure live in relative poverty, faces output price fluctuations, and constantly struggle with the environment's adversities. In addition, much-discussed climate change affects the poor via the agriculture sector since poverty tends to be concentrated in rural areas. The food affordability of the poor is tightly tied to climatic patterns as their wages and livelihoods

[5] Gradual release may allow the labor force in the agriculture sector to develop skills necessary for the manufacturing sector. In addition, agriculture productivity growth would accelerate the growth of the manufacturing sector facilitating labor force absorption from the agricultural sector (Bustos et al., 2016).

is a function of climatic conditions (Hertel et al., 2010; Hertel & Rosch, 2010). The burden of supporting rural agricultural poor households' adaptation to extreme climatic events and adversities of environment-such as human-elephant conflict- is on the policymaker. The designed programs by the policymaker with an emphasis on poverty reduction will help poor farmers in two ways. First, increased income will help them invest in technologies that help them mitigate the impact of natural calamities. Second, farmers will adopt market-based instruments like crop insurances to insure them from environmental adversities. Widespread adoption of market-based instruments like insurances, indeed, release the policymaker from providing compensations that are complicated, inefficient, fiscally unrealistic, and inadequate.

Figure 5: Annual Expenditure (USD million) for Agrochemicals and Fertilizer Imported by Sri Lanka



Source: Author's illustration using data from FAOSTAT, Food and Agriculture Organisation

Although agricultural intensification and subsequent productivity growth resulted in welfare improvements and substantial direct environmental benefits, including reduced growth of land conversion and increased availability of marginal lands to be released into alternative ecosystem services[6] (Burney et al., 2010), we cannot ignore the adverse environmental effects of fertilizer misuse. Chemically polluted water sources, soil degradation, and chemical run-off are reported beyond the cultivated areas (Table 1).

[6] As an example, such land can be used for pollinator habitats.

These environmental costs are substantial and threaten the long-term sustainability of the high-input use agriculture systems. Moreover, Pingali (2012) reported a lack of policies and research to incentivize the rationale use of inputs even in the global context. The scientific evidence of fertilizer pollution and substantiated and unsubstantiated claims of harmful health effects are used to justify the ban on chemical fertilizer along with agrochemicals.

Table 1: Studies that Document Fertilizer Overuse and Run-off to Drinking Sources

Criteria	Descriptions	Study
Overuse of fertilizer	Upcountry vegetables and potato farmers apply fertilizer excessively above the recommended level by the Department of Agriculture (DOA.[a])	Wijewardena (2001)
	Overuse of N, P, K in Nuwaraeliya vegetable farming areas	Ariyapala & Nissanka (2006) Upekshani (2018)
Fertilizer run-off to drinking water sources	Higher nitrate-N in wells in up-country	Wijewardena et al. (1999)
	High concentrates of nitrate-N in groundwater in Kalpitiya and Jaffna	Liyanage et al. (2000); Kuruppuarachchi (1995); Jeyaruba & Thushyanthi (2009)

Note: a) DOA=Department of Agriculture

Source: Author's compilation

EVIDENCE-BASED APPROACH FOR A GREEN ECONOMY WITH EMPHASIS ON TRADEOFFS

Indeed, it is undeniable that negative externalities of synthetic fertilizer exist, and there should be coping mechanisms and mitigations in place for the negative externalities. However, myths like Sri Lanka is a heavy fertilizer and agrochemical user need to be debunked. Table 2 illustrates that Sri Lanka's average nutrient budget, which indicates the difference between nutrient input and nutrient removal through crop harvest, is low, around 5.96 Kg/Ha. Developing countries like India and Bangladesh and developed countries like Switzerland and the UK show high nutrient surpluses leading to higher environmental risk than Sri Lanka. The Food and Agriculture Organization (FAO) classifies Sri Lanka among the Green countries: those with budgets between zero and the median global nitrogen deposition rate (FAOSTAT, 2020). Similarly, Sri Lanka uses a moderate amount of pesticides per hectare (Figure 6). Thus, policymakers of Sri Lanka need to assess the risk accurately and carefully weigh the tradeoffs of policy initiatives that intend to transform the country's agriculture sector radically. Specifically, reduced agricultural sector productivity would inhibit industrial growth and result in economic contraction, narrowing the available fiscal space for funding meaningful green initiatives. In addition, given that nearly a quarter of the workforce is in the agriculture sector, the productivity losses may result in unprecedented welfare effects, especially on the rural poor. Further marginalization of the poor farmers would expose them to climatic and natural vagaries, motivating them to extensively expand agricultural land use, exerting pressure on the country's forest cover and increasing conflicts with the environment.

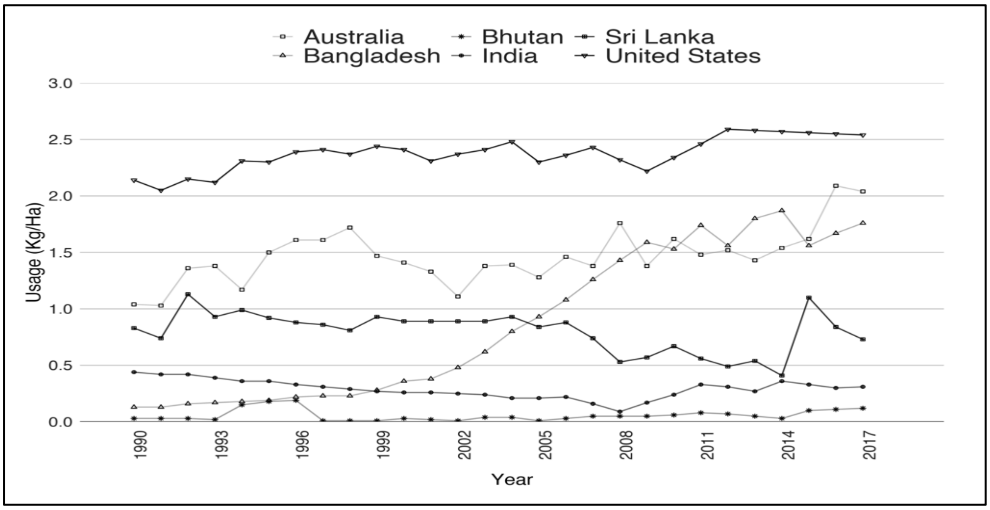
Table 2: Nutrient Balance of selected countries.

Country	Total Cropland nutrient input (Kg/Ha)	Share of Synthetic Fertilizer Input	Crop Removal of nutrients (Kg/Ha)	Balance (Input-Output) (Kg/Ha)	Cereal Yield (Kg/Ha)
Bangladesh	217.046	71%	104.853	112.194	4790.70
India	155.752	67%	54.051	101.700	3247.90
Madagascar	24.859	32%	22.749	2.110	4003.90
Palestine	5.582	NA	21.617	-16.035	NA
Sri Lanka	43.499	67%	37.531	5.968	3761.60
Switzerland	298.741	35%	57.341	241.400	6203.70
Trini. & Tobago	330.920	42%	9.278	321.642	1987.20
United Kingdom	271.778	62%	79.850	191.928	6788.70

Notes: Total cropland nutrient input is the sum of synthetic fertilizer input, manure applied to soils, atmospheric deposition, and biological fixation.

Source: Author’s illustration using data from FAOSTAT, Food and Agriculture Organisation

Figure 6: Pesticides Usage (Kg/Ha) by Selected Countries



Source: Author’s illustration using data from FAOSTAT, Food and Agriculture Organisation

It is essential to address the overuse of chemical fertilizers in intensively cultivated areas like Up-Country, Kalpitiya, and Jaffna. Location-based soil testing and provision of fertilizer at the subsidised price based on the soil requirement and sophisticated extension services might help mitigate the negative externality. However, I am weary of the suggestion that abolishing fertilizer subsidies will result in economically and environmentally sound outcomes. First, such a move will have distributional welfare effects, incentivizing marginal farmers to move out of agriculture without proper training to join the manufacturing sector. Additionally, given that the manufacturing sector's ability to absorb that labor force is doubtful at present, such a move may generate agrarian unrest with widespread societal ramifications. Second, producers will opt for substitutes like manure. The application of excessive manure has negative implications like run-off. In addition, poor manure management practices can lead to the high prevalence of E-coli in the produced food and make organic produce susceptible to faecal contamination (Mukherjee et al., 2004). In addition, Herath et al. (2015) reported that the overuse of Urea compared to TSP and MOP was controlled by the subsidy programme as it made TSP and MOP available at the same price as Urea. Thus, removing subsidies can pave the way for imbalanced fertilizer application.

Policies can be designed to make excessive harmful fertilizer users internalise the cost. As an example, widely available evidence suggests that some farmers use nitrates-N excessively (Kuruppuarachchi, 2012). One mechanism is to tie fertilizer subsidy to soil testing. Given the cost of individual soil testing, the most cost-effective way will be imposing a tariff on Urea imports to increase the domestic price to a non-prohibitive level. This revenue can be used to facilitate the gradual increase of organic farming scientifically and commercially. Training farmers for good agricultural practices, supporting organic producers to get required labelling, and creating digital platforms to integrate organic producers into the global market are a few concerns on which the policymaker shall allocate the tariff revenues.

CONCLUSION

In the backdrop of drastic policy change to accelerate organic agriculture in Sri Lanka, this perspective attempts to find an evidence-based approach for a green economy, adequately accounting for tradeoffs. First, I discussed the positive impact of high-input use agriculture on the environment. High input use agriculture restricts the extensive expansion of agricultural land use, increases GDP per capita in the developing countries, increases the fiscal space for meaningful green investments, and increases the resilience of economically marginal farmers against extreme climatic events and environmental vagaries. Second, the negative environmental externalities of high input use agriculture, notably due to nitrogenous fertilizer overuse were discussed. Finally, I deliberated about an economically less harmful way towards a green economy harnessing the productivity gains of high-input use agriculture with a mechanism to internalise the externalities of nitrogenous fertilizer usage. I suggest site-specific soil testing, linking fertilizer subsidy with site-specific fertilizer recommendation, and deterring the overuse of nitrogenous fertilizer using a tariff. On the other hand, as overreaching environmental repercussions may generate from abolishing the fertilizer subsidy through substitution effect, productivity effect and imbalanced fertilizer application, continuing the subsidy while promoting good agricultural practices can be suggested.

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