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Rice Production in Madagascar

Challenges to Self-Sufficiency

Vaishali Ashtakala, Joanne Tan (AFR), Timila Dhakhwa (MCM), and Yipei Zhang (SPR)

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Rice Production in Madagascar – Challenges to Self-Sufficiency
Republic of Madagascar
Prepared by Vaishali Ashtakala, Joanne Tan (AFR), Timila Dhakhwa (MCM), and Yipei Zhang (SPR)

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ABSTRACT: *The Malagasy government aims for self-sufficiency in rice production by 2027, targeting 6 million tons in 2024 and 11 million tons by 2030. Despite recent production increases, challenges such as competition from cheaper imports, low productivity, and climate change persist. This paper analyzes the impact of import competition on local markets, utilizing historical data on tariffs and VAT. It assesses potential rice output under various scenarios and discusses strategies for enhancing productivity sustainably. Findings indicate significant room for improvement in rice yields, highlighting the need for targeted supply-side policies to bolster local production without adversely affecting prices.*

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REPUBLIC OF MADAGASCAR

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RICE PRODUCTION IN MADAGASCAR—CHALLENGES TO SELF-SUFFICIENCY[1]

The Malagasy government aims to achieve self-sufficiency in rice production by 2027. In line with the national strategy on the development of rice cultivation (SNDRIII), adopted in 2023, Madagascar seeks to produce 6 million tons of rice in 2024 and to eventually reach an annual rice production of 11 million tons by 2030. To meet its goal, however, the country faces numerous challenges, including stiff competition from cheaper rice imports, chronic low productivity, and climate change. In this paper, we examine current issues faced by the rice sector in Madagascar, notably with regards to productivity. We estimate the impact of competition from rice imports on the local rice market, by exploiting historical changes to import tariffs and value-added taxes (VAT). Using data from the Food and Agriculture Organization (FAO), we study the maximum potential rice output, under different climate and input scenarios. Lastly, we examine possible supply-side strategies to sustainably raise future rice productivity in Madagascar, taking into consideration relevant environmental concerns, the impact of climate change as well as climate-smart agricultural practices.

A. Rice Production in Madagascar: Background and Recent Developments

Table 1. Madagascar: Annual per Capita Consumption of Rice
(kg/capita/year)

Gambia	256.4
Bangaldesh	246.9
Vietnam	228.1
Thailand	178.9
Madagascar	153.5
China	132.3
India	99.0
Nigeria	33.1
Pakistan	17.7

Source: FAO Food Balances Database

1. **In Madagascar, rice is the most widely consumed and produced crop, accounting for a substantial portion of total agricultural production.** The average Malagasy individual consumes 153.5 kilograms of rice annually, which represents more than half of their total daily caloric intake (Table 1).[2] According to the 2021 National Household Survey, 27.2 percent of households reported engaging in agricultural activity within the previous week, with 49.5 percent of such households cultivating rice paddies primarily for subsistence. Since 2002, annual rice production has increased by 76 percent, reaching 4.6 million tons in 2022. However, despite local cultivation efforts by small rural farmers, rapid population growth since 1960s has intensified Madagascar's reliance on rice imports to meet demand. While the

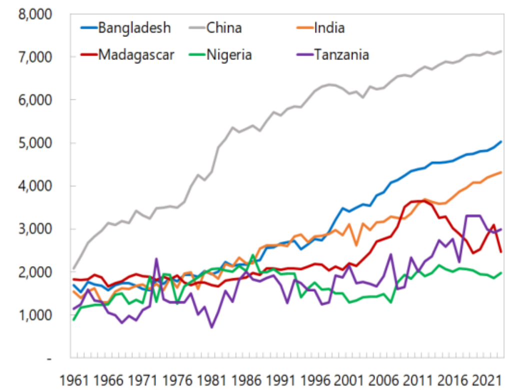
[1] Prepared by Vaishali Ashtakala, Timila Dhakhwa, Joanne Tan, Yipei Zhang. The team gratefully acknowledges the helpful inputs and feedback from experts of the Food and Agriculture Organization and the World Bank Group, as well as fruitful discussions with staff from the Ministry of Agriculture.

[2] FAOSTAT Food Balances database 2022 estimate.

population grows at an annual average rate of 3 percent, rice production has only increased by an average of 2 percent per year, resulting in a persistent production gap.

2. **Despite growing levels of rice production, Madagascar's ability to meet local rice demand has dwindled since the 1960s, due to stagnating productivity**. After a severe rice crisis in the 1960s, the government implemented policies to stabilize producer and consumer prices and promoted the use of fertilizers. However, from the 1970s, government policies vacillated between intervention and market liberalization. In the 1970s, Madagascar's rice yields were comparable to or even exceeded those of other rice-producing countries (Figure 1). However, yields in countries like Bangladesh, began to outpace Madagascar's in the 1970s, largely due to government investments in irrigation and developing infrastructure.

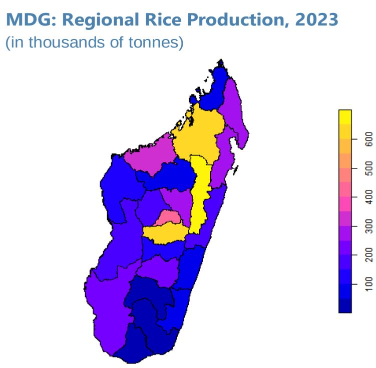
Figure 1. Selected Economies: Top Rice Producing Countries Yields
(In kg/hectare)



Source: FAOSTAT

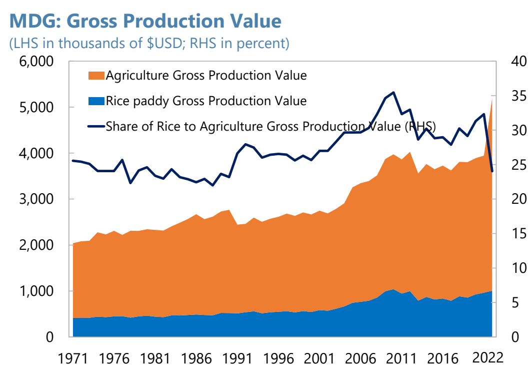
Figure 2. Rice Production and Consumption

Production varies significantly based on regional climate differences.



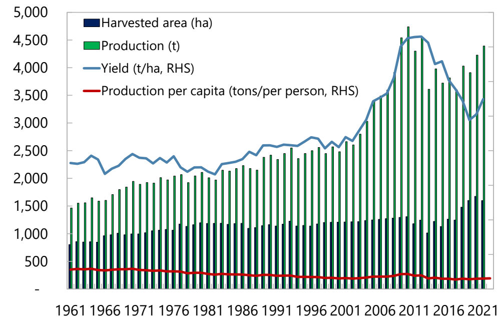
Source: MINAE.

Rice paddy accounts for 24 percent of total agricultural gross production value, totaling $1,006,030 in 2022.



Sources: Rice Observatory; FAO STAT; USDA; and IMF staff calculations.
Note: Agricultural production includes forestry and fishing.

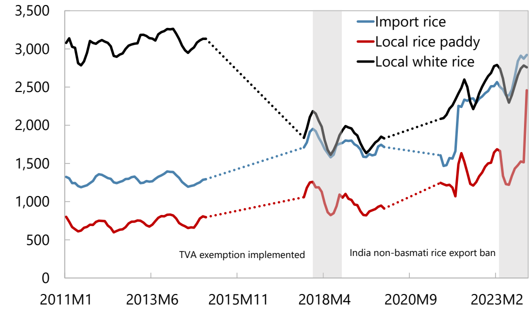
MDG: Harvested Area, Yield and Production
(LHS in thousands)



Sources: FAO STAT; and IMF staff calculations.

Rice production per capita has been dwindling with large population increases and falling yield since the early 2000's.

MDG: Average Local and Import Rice Price
(In ariary/kilogram)



Sources: Authorities' data; and IMF staff calculations.
Note: Data contains breaks due to inavailability, data has been interpolated.

Imported rice prices have remained lower than local white rice varieties since 2011.

3. **Madagascar's rice sector has faced numerous longstanding challenges, resulting in sluggish production.** Across the country, various planting methods are employed in different regions to address specific agricultural challenges and improve productivity. In the central highlands, where population density is the highest, cultivation methods such as agroforestry systems are common. In regions along the east coast, these systems integrate crops like clove, vanilla, coffee, and cocoa with fruit trees or livestock, enhancing biodiversity and soil fertility. The System of Rice Intensification (SRI) is also employed in the central highlands to increase rice yields while reducing water usage and input costs.[3] In contrast, the eastern coast of Madagascar, which experiences abundant rainfall, often relies on traditional methods like slash-and-burn agriculture (*tavy*) and permaculture gardens. These methods are adapted to the region's climatic conditions and are a means of subsistence farming among rural communities.

4. **The local rice market is sensitive to changes in import prices and quantity.** Domestically produced rice often incurs higher production costs due to limited mechanization and input usage, making it less competitive in price compared to imported rice. In 2023, the export ban on rice imposed by the Indian government significantly impacted imports, as Madagascar sources a substantial portion of its rice imports from India and Pakistan. Trade from India and Pakistan

[3] SRI is method of rice cultivation that includes the planting of young seedlings, the adequate spacing between rice plants, the application of organic fertilizer and the maintenance of optimal soil moisture via controlled irrigation. Despite originating in Madagascar in the 1980s, SRI adoption across the country remains limited. A study among rice farmers in Manombo by Moore et al. (2024) cites factors including perceptions of SRI as being more time and labor intensive than traditional methods, lack of farming tools and organic fertilizer, inadequate access to fast-growing rice seeds suitable for SRI, as well as lack of technical knowhow as reasons for the low adoption among Malagasy rice farmers. More broadly, Moser and Barrett (2006) find that financial liquidity constraints prevent small scale farmers in Madagascar from adopting higher yield rice production methods like SRI.

accounted for 98 percent of total imported rice to Madagascar in 2022, leaving the country vulnerable to policies enacted by its trading partners.[4]

5. **While some reforms have targeted local production, other policies have sought to keep prices affordable for the local populace.** One notable policy is a value added tax exemption (previously at 18 percent) on both imported and locally produced rice, in place since July 2008, in response to soaring international food prices and cyclone damage to local production (David-Benz et al., 2014). While VAT exemptions on rice have been credited with maintaining affordable rice prices for domestic consumers, they also exact a high fiscal cost, diverting government resources away from other public spending needs. By some estimates (Wen et al., 2021), VAT exemptions on local and imported rice amount to around 1.3 percent of GDP (1.1 percent from the former and 0.2 percent from the latter). In addition, the exemption of customs duties on imported rice since 2005 is estimated to cost another 0.2 percent of GDP annually.

6. **In the wake of supply chain disruptions following the Covid pandemic and Russia's invasion of Ukraine, the Malagasy authorities elaborated a national strategy to attain rice self-sufficiency by 2027.[5]** The guiding principles of the national strategy revolve around i) raising productivity and local rice production, ii) promoting competitiveness, and iii) reinforcing agricultural R&D. Implementation challenges continue to hamper Madagascar's efforts to boost rice production and reduce its reliance on imports. Although comprehensive policy frameworks are developed, translating these into effective action on the ground remains difficult. Issues such as inadequate infrastructure, limited irrigation investment, and insufficient access to quality seeds, fertilizers, and machinery hinder progress. Compounding these issues are a lack of coordination among government agencies and bureaucratic delays, which weaken the impact of reforms. The persistence of traditional farming practices and limited agricultural extension services further slow the adoption of modern techniques. Additionally, climate shocks, including droughts, cyclones, and erratic rainfall, frequently devastate rice crops, discouraging investment in rice farming and making non-subsistence production financially precarious for smallholders.

7. **In the following sections, we examine the impact of import competition on local rice production as well as possible reform measures that could boost local production**. Import competition has been a significant factor affecting local rice production. The influx of cheaper and tax-free imported rice has led to a decline in local production, as farmers find it difficult to compete with the lower prices of imported rice. This has resulted in a reliance on imports to meet domestic demand, which can be problematic in times of global supply disruptions. On the other hand, measures targeting local production have focused on improving agricultural practices, providing subsidies, and investing in infrastructure to support rice farmers. These measures aim to increase productivity, ensure food security, and reduce the country's dependence on imported rice. Potential reform measures to boost local production include promoting sustainable agricultural practices,

[4] WITS data (2023) HS 6 Digit Code 100630 for semi-milled or wholly milled rice.

[5] The Ministry of Agriculture and Livestock's rice self-sufficiency strategy for 2022-2030 is detailed in the National Strategy for Rice Production (SNDR III). Since then, the issue has become a key presidential priority, with 2027 as the target year for full rice self-sufficiency.

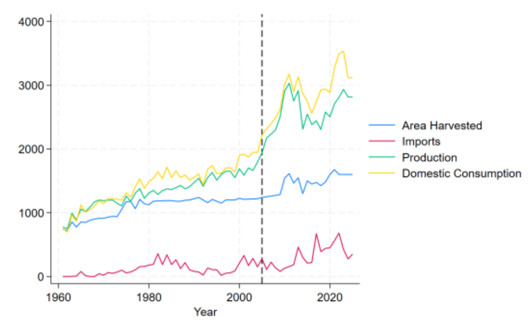
such as SRI and permaculture techniques, which can lead to higher yields and more resilient crops. Additionally, improving access to quality seeds, fertilizers, and irrigation systems, as well as providing training and support to smallholder farmers, could enhance local rice production.

B. Levelling the Playing Field - Measuring Price Elasticities of Rice Demand and Supply in Madagascar

8. **Levelling the playing field and removing custom duty exemptions may incentivize local rice production, by raising the price of rice in local markets, thereby encouraging local farmers to increase production beyond their subsistence level.** In this section, we exploit two events, namely the one-off imposition of tariffs in 2005 and the VAT exemption on imported rice from 2008, to estimate the price elasticities of rice demand and supply in Madagascar. Knowing these price elasticities would provide a sense of whether the removal of tariff or tax exemptions would raise local production and the extent to which Malagasy households would be affected by an increase in rice prices.

9. **Local rice production increased following a one-off tariff increase on imported rice in 2005.** The dashed line in Figure 3 marks a temporary increase in the average tariff rate applied on imported rice from 0 to 17.5 percent in year 2005[6]. As shown in Table 2, we observe a cumulative increase in local rice production from the level in 2005, suggesting that local rice production gradually picked up as imported rice became more expensive. Indeed, by 2010, local rice production was nearly 40 percent greater than in 2005.

Figure 3. Rice Production, Imports and Consumption in Madagascar, 1961–2025



Source: USDA Foreign Agricultural Service
Source:

Table 2. Madagascar: Response of Local Rice Production in Madagascar to the 2005 Tariff Increase

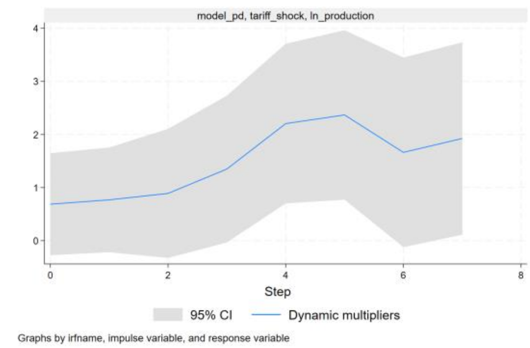
Year	Percent change in local production from 2005
2005	0
2006	2.8%
2007	5.9%
2008	15.4%
2009	33.9%
2010	39.7%

Source: USDA Foreign Agricultural Service

[6] This is the average of effectively applied rates weighted by the product import shares corresponding to each partner country.

10. The price elasticity of supply (PES) is estimated around 2 percent at a 4-to-5-year horizon. We estimate the price elasticity of supply (PES) based on the 2005 event, using the time series of local rice production in Madagascar. The shock to rice price is indexed by the tariff shock, which is considered a quasi-natural experiment. By running a simple local projections (LP) model, we find that local production is relatively inelastic in the short-term following the price shock but is estimated at around 2 at 4-5 years following the price shock, that is, a 1 percent increase in rice price would lead to an increase in local rice production of around 2 percent (Figure 4). Further details on the estimation strategy are presented in Text Box 1.

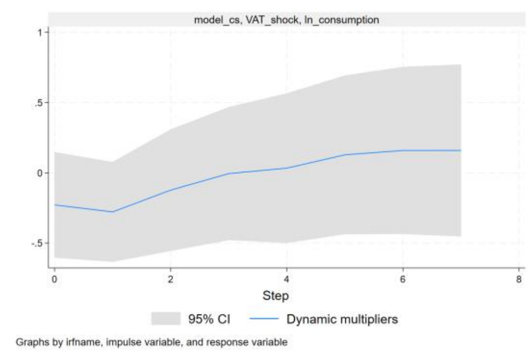
Figure 4. Impulse Response of Local Rice Production



Source: IMF staff estimates and USDA Foreign Agricultural Service

11. The price elasticity of demand (PED) is close to zero. We then estimate the demand elasticity following a price shock i.e. change in local rice consumption in response to change of rice price. In this exercise, we use the introduction of a VAT exemption in 2008. In contrast to a tariff shock which only directly affects the price of imported rice, a VAT exemption affects the price of both imported and domestically produced rice. Hence it provides a better indicator of the overall price change faced by consumers. Our estimates show that local rice consumption is inelastic to rice price (Figure 5). Given that rice is the main staple in Madagascar, this finding is expected. Further details on the estimation of PED can also be found in Text Box 1.

Figure 5. Impulse Response of Local Rice Consumption



Source: IMF staff estimates and USDA Foreign Agricultural Service

12. A balanced approach is therefore warranted when considering policies related to removing tariffs or VAT exemptions on imported rice. While higher tariffs may raise local rice supply with some lag, the immediate impact on rice prices would lower the welfare of households in Madagascar, whose demand for the essential staple is inelastic. Yet, as mentioned in the previous section, the fiscal cost of VAT exemptions on imported rice is high, diverting government spending from other pressing needs. One possible middle ground would be to remove VAT exemptions on high-quality, specialty rice consumed by affluent households while maintaining the exemptions for low-quality broken rice consumed by poorer households. Such a policy could raise the competitiveness of locally produced non-broken rice, thereby spurring local rice production while shielding modest households from higher prices. However, enforcing the tax regime distinction between high- and low-quality rice could be challenging in practice, and would require strengthening controls to limit the risk of tax evasion and misclassification.

13. More generally, a comprehensive VAT reform on agriculture-related products could incentivize investments in the rice sector. Apart from the VAT exemption on imported rice which depresses local rice prices and hampers local production, current VAT exemptions on agricultural inputs do not sufficiently target and incentivize productivity-boosting investments and mechanization. Reconsidering the VAT exemption on imported rice would not only have a direct positive impact on local rice production, as discussed above, but also leave greater room for targeted VAT exemptions on agriculture inputs that are crucial to productivity. Furthermore, since low rates of mechanization and fertilizer use are mainly prevalent among smaller-scale rice plantations, such VAT exemptions on farming inputs could be targeted at farmers with revenues below a given threshold (Rota-Graziosi et al., 2015).

Box 1. Estimating PES and PED using Local Projections (LP)

In our estimation of PES and PED, we estimate dynamic multipliers using LP, where we treat local rice production or consumption as the response variable and the tariff or VAT shocks as the exogenous variable. Specifically, we estimate the effect of the exogenous variable x_t on the response variable h steps ahead by estimating the following local projection for horizon $h = 0, 1, 2, \ldots , H - 1$:

$$y_{t+h} = \emptyset_h x_t + \boldsymbol{z}_t \boldsymbol{\delta} + u_{t+h}$$

where the coefficient of interest is the dynamic multiplier coefficient $\emptyset_h$. Additional controls $\boldsymbol{z}_t$ are included i.e. further lags of the endogenous variables. The estimation tables below give the dynamic multipliers at each horizon following the event.

```
Local-projection impulse-responses

Sample: 1962 thru 2018                                Number of obs       = 57
                                                      Number of impulses  =  2
                                                      Number of responses =  1
                                                      Number of controls  =  0
```

	IRF coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_production						
ln_production						
F1.	.9397081	.0319629	29.40	0.000	.8770619	1.002354
F2.	.9111327	.0327957	27.78	0.000	.8468543	.9754112
F3.	.8908726	.0404335	22.03	0.000	.8116244	.9701207
F4.	.8608419	.04599	18.72	0.000	.7707033	.9509806
F5.	.8431713	.0500131	16.86	0.000	.7451475	.941195
F6.	.8355437	.0530929	15.74	0.000	.7314836	.9396038
F7.	.8280103	.0594024	13.94	0.000	.7115837	.9444369
F8.	.828073	.0602838	13.74	0.000	.7099189	.9462271
tariff_shock						
ln_production						
--.	.6865813	.4899061	1.40	0.161	-.273617	1.64678
F1.	.7687383	.5026705	1.53	0.126	-.2164778	1.753954
F2.	.8900548	.6197365	1.44	0.151	-.3246064	2.104716
F3.	1.349463	.7049024	1.91	0.056	-.0321206	2.731046
F4.	2.205686	.7665657	2.88	0.004	.7032448	3.708127
F5.	2.368127	.8137712	2.91	0.004	.7731647	3.963089
F6.	1.662993	.9104794	1.83	0.068	-.1215142	3.4475
F7.	1.924584	.9239889	2.08	0.037	.1135988	3.735569

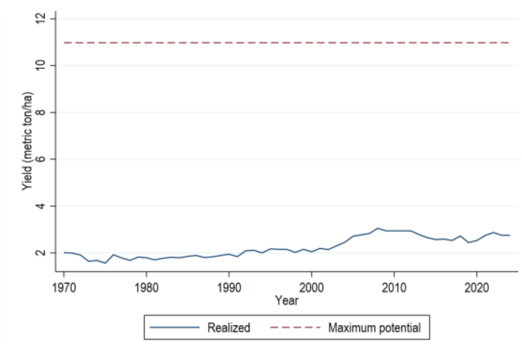
```
Note: IRF coefficients for exogenous variables are dynamic multipliers.
Impulses:  ln_production tariff_shock
Responses: ln_production
```

Source: IMF staff estimates using USDA IPAD data, WITS

C. Raising Local Rice Production – Potential and Pitfalls

14. Despite recent improvements in productivity, Madagascar's rice yield remains far below potential (Figure 6). While the rice yield improved gradually over 1980-2010, it has stagnated since the late 2000s at around 2.75 tons per hectare, far below FAO country-level estimates of maximum potential yield of 11 tons per hectare.[7] As mentioned, the chronically low yield in Madagascar can be attributed to several factors, including weak agricultural inputs such as mechanization, irrigation and fertilizer use, natural disasters including drought, flooding, cyclones and locusts, land degradation as well as inadequate land rights management.[8]

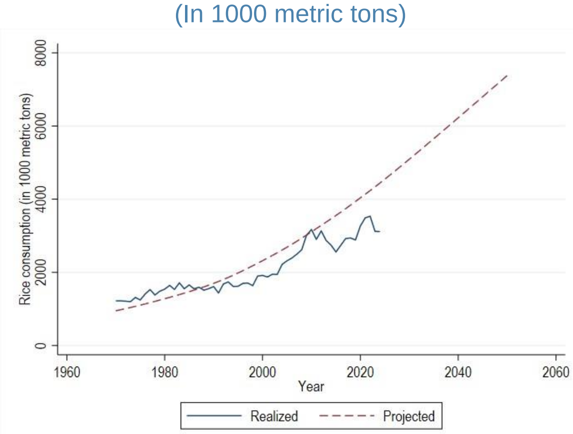
Figure 6. Rice Yield in Madagascar (Realized vs potential in metric ton/hectare)



Sources: Authorities' and IMF staff estimates. FAO projections.

15. In tandem with the rise of the Malagasy population from 31 million in 2023 to nearly 52 million by 2050, local rice consumption is expected to rise to 7.4 million metric tons in 2050, far above current local production levels (Figure 7).[9] To meet local demand, raising the productivity of existing rice fields should be prioritized. Indeed, according to FAO and USDA projections, if rice yields in Madagascar were at their maximum potential of 11 tons per hectare, rice production in 2023 would have been at around 17.5 million metric tons, 3.4 times its realized 2023 production level of 5.3 million metric tons and comfortably above local population needs, even if the current size of rice cultivation plots were unchanged. Yet, while

Figure 7. Projected Annual Rice Consumption in Madagascar
(In 1000 metric tons)



Sources: USDA and FAO projections.

[7] FAO estimates of maximum potential yield are based on geo-spatial data on historical climate attributes, soil and terrain conditions, land cover and protected area. Estimates of maximum potential yield also assume that there are ideal input conditions, including 200mm/m of water available under irrigation, fertilizer use, and mechanization.

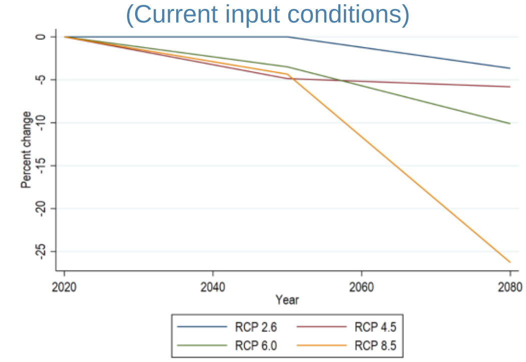
[8] According to a 2020 report on the irrigation sub-sector in Madagascar, World Bank experts found that only half of cultivated areas with irrigation infrastructure did actually benefit from irrigation, due to the deterioration of existing infrastructure. They estimate that modernizing the existing irrigation infrastructure would reap greater production benefits compared to constructing new irrigation infrastructure and would be less costly.

[9] Projections assume an average annual consumption of 143 kg of rice per person.

maximum potential yields under optimal conditions would be sufficiently high for self-sufficiency, such ideal conditions may not be achievable. According to World Bank experts, rice yields in Madagascar could realistically reach 6 to 8 tons per hectare at best, even with improvements to rice farming systems. [10]

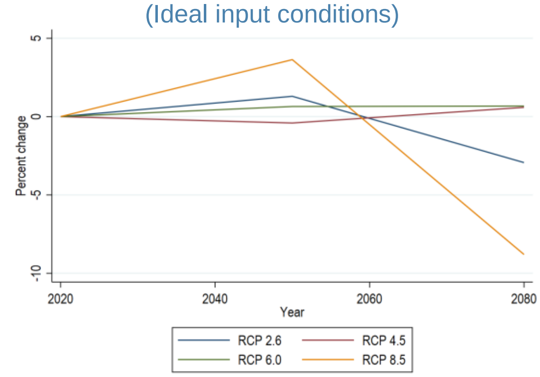
16. At current input levels, the worsening of climate conditions is expected to adversely affect future rice production, hampering self-sufficiency and exacerbating food insecurity. Using FAO projections of potential rice yield under different climate scenarios, we calculate the projected rice production losses from 2020 (Figure 8). Under Representative Concentration Pathway (RCP) 4.5, where greenhouse gas emissions peak in 2040 and decline thereafter, annual potential rice yield in Madagascar would be 5 percent lower by 2050 and continue to fall over time.[11] Should greenhouse gas emissions continue to rise after 2040, the projected losses in potential rice yield would be even larger. For instance, under RCP 8.5, a business-as-usual scenario under which greenhouse emissions continue to rise unabated, annual rice production in Madagascar would decline by 25 percent by 2080. Given that FAO projections are based on agro-climatic conditions and exclude natural disaster shocks including cyclones, droughts, and floods, which would intensify with the climate crisis, these projections likely underestimate the adverse impact of climate change on rice production in Madagascar.

Figure 8. Decline in Madagascar's Rice Production Under Different RCP Scenarios
(Current input conditions)



Sources: IMF staff estimates and FAO projections.

Figure 9. Decline in Madagascar's Rice Production Under Different RCP Scenarios
(Ideal input conditions)



Sources: IMF staff estimates and FAO projections.

17. However, access to irrigation and sustainable fertilizer use could mitigate the threat of climate change on Madagascar's rice production. In their study of the impact of climate change on rice production in Africa, Van Oort and Zwart (2017) find that by adopting more heat resistant rice varieties and irrigation, rice production in East Africa could rise by as much as 25

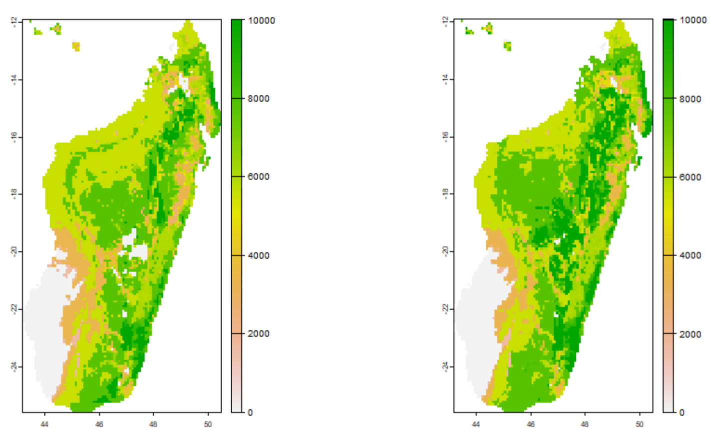
[10] The system of improved rice farming, or the *Système du Riz Amelioré (SRA)*, is a less input demanding rice cultivation method compared to the SRI and adopts only selected features of the SRI, such as the planting of young rice seedlings and leaving adequate spacing between individual rice plants (World Bank Background Report, 2022).

[11] RCP 4.5 corresponds to a future global mean temperature rise of around 2-3 degrees Celsius and is regarded by the IPCC as a stabilization scenario, under which all countries impose emission prices that rise over time.

percent, due to CO_2 fertilization and, to a lesser extent, lower rates of cold sterility.[12] Likewise, FAO projections show that, with ideal input levels, including irrigation and fertilizer access, rice production in Madagascar could be more resilient to climate change (Figure 9). Under RCP 4.5 and ideal input conditions, for instance, rice production would remain close to its 2020 baseline in 2050, even rising slightly in 2080. Once again, it should be noted that these results assume adequate water availability for irrigation and abstract from natural disaster shocks and should therefore be regarded as a highly optimistic projection of future rice production in Madagascar. Indeed, should climate change disrupt the water cycle and hence water availability in Madagascar, adequate water access for rice cultivation would be jeopardized. Moreover, higher CO_2 concentration, while promoting rice growth, could lower the protein content of rice, thereby diminishing its nutritional value (Ujiie et al., 2019).

18. **Intra-country changes in agricultural suitability in the face of climate change may further complicate the achievement of Madagascar's self-sufficiency goal.** As shown in Figure 10, under RCP 4.5, the projected suitability index for wetland rice cultivation is expected to shift in the coming decades, increasing in the north and east of the country, while declining in the south west over the coming decades. With population growth and competing land use needs including biodiversity conservation, adapting to shifting rice cultivation suitability while accomodating other land needs would be a challenge and would require an adequate legal framework for land use management.

Figure 10. Projected Suitability Index for Wetland Rice Cultivation in Madagascar under RCP 4.5



a) 2011-2040 **b) 2041-2070**

Source: IMF staff estimates and FAO projections.

[12] Assuming heat resistant rice species and adequate irrigation, higher CO_2 concentration raises the rate of photosynthesis, thereby promoting rice plant growth. The authors note that cold-induced sterility in rice plants in East Africa typically occurs in the highlands when temperatures fall below 22 degrees Celsius.

D. Climate-Smart Agriculture (CSA) Practices for Rice Cultivation

19. Policies to boost local rice productivity need to be sustainably implemented. Madagascar's second Nationally Determined Contribution (NDC) identifies rice farming and cultivated soils as contributors towards agricultural GHG. The NDC recommends a wide range of agricultural initiatives such as climate-smart agriculture, organic agriculture, Integrated Resilient Rice Models (MIRRs), conservation agriculture as well as setting up monitoring and technological capacity-building mechanisms. While the Ministry of Agriculture and Livestock has identified several measures to boost local rice production, including the adoption of high-yield hybrid rice seeds from China, an improved access to fertilizer and an increase in the allotted land for rice cultivation, careful consideration of their secondary socio-economic and environmental impacts is needed (Text Box 2). Rice cultivation practices should encourage prudent water and fertilizer use without sacrificing yield given the methane and nitrous oxide emissions associated with flooded rice paddy fields and the long-term adverse impacts of chemical fertilizers on soil fertility and the environment.

Box 2. Hybrid Rice – A Panacea for Madagascar's Self-Sufficiency Goals?

Developed in 1974 by Chinese agronomist Yuan Longping, hybrid rice involves crossbreeding two distinct parent rice species. Such crossbreeding leads to heterosis, or "hybrid vigor", which significantly increases the yield of the offspring plant compared to their purebred counterparts, with yields of some strains of hybrid rice reaching more than 15 tons per hectare in studies conducted in the Hunan province of China. Furthermore, hybrid rice varieties are generally palatable and easily substitutable with non-hybrid rice varieties among consumers.

Since the enactment of a south-south cooperation agreement between China and Madagascar in 2018, the adoption of hybrid rice has been incorporated into Madagascar's national rice strategy. Pilot studies conducted with Chinese hybrid rice seeds in Madagascar have attained yields of around 11 tons per hectare. To date however, data on the inputs used to obtain these results are not available. Furthermore, no study has been conducted comparing the yields of local and hybrid rice varieties under the same conditions. Since pilot studies of hybrid rice yields have typically been conducted under ideal input conditions, while the yield of local rice varieties is often measured using realized rice yields under non-controlled settings, it is hitherto unclear if the yield gains from using hybrid rice have been accurately established.

In addition, other factors should be considered before the adoption of hybrid rice is scaled up. Unlike purebred rice varieties, hybrid rice seeds cannot be saved and replanted from the current crop, which means that these seeds must be newly procured with each planting season. Furthermore, compared to other local rice varieties, hybrid rice seeds are around ten times more expensive than local rice seeds and require greater inputs including chemical fertilizers and water, which would have environmental implications. Because of these factors, hybrid rice cultivation is likely to be unaffordable for small-scale farmers in the absence of generous government subsidies, which could in turn weigh heavily on the government budget. Moreover, the widespread adoption of hybrid rice may lead to the crowding out of local rice varieties and a loss of crop diversity, thereby lowering the resilience of Madagascar's rice production to diseases and pests. Indeed, some of these local varieties may be more resistant to extreme climatic shocks such as cyclones and floods.

Source: FAO staff, Ma and Yuan (2015)

20. Rice production contributes to the release of Green House Gas (GHG), particularly methane (CH_4) as well as nitrous oxide (N_2O). The Intergovernmental Panel on Climate Change (IPCC) has indicated a Global Warming Potential (GWP) for methane between 84-87 when considering its impact over a 20-year timeframe (GWP20) and between 28-36 when considering its impact over a 100-year timeframe (GWP100). Nitrous oxide on the other hand has a GWP of 289 over a 20-year period and 298 over a 100-year time span. Rice grown in flooded fields has been found to be the main reason for the release of both methane as well as nitrous oxide, which is also impacted by over-application of fertilizers.

21. Flooded fields create an anaerobic condition ideal for bacteria called methanogens that release methane as they decompose organic matter. Nitrous oxide is produced primarily due to microbial processes in the soil called nitrification and denitrification. Nitrification is an aerobic process where soil bacteria convert ammonia to nitrate which produces nitrous oxide as a byproduct. Denitrification occurs under anaerobic conditions when the soil is waterlogged, such as in rice paddies during which soil bacteria convert nitrate into nitrogen gas releasing nitrous oxide as a byproduct. Estimates suggest that paddy rice production is responsible, on average, for 16 percent of agricultural methane emissions or 4.3 percent of total agrifood system emissions.

22. Climate-Smart Agricultural (CSA) practices that include sustainable water management practices and careful application of fertilizers are key strategies in mitigating methane and nitrous oxide production. CSA is an integrated approach to managing agricultural production that can achieve the "triple win" of the following: (1) economic gains, (2) climate resilience, and (3) lower GHG emissions (Sutton et al., 2024). There are several on-farm practices available to reduce rice paddy emission such as direct seeding, midseason drainage, residue management, improved fertilization, alternate wetting and drying (AWD), and integrated rice and fish farming (Searchinger and Adhya, 2015). In fact, System of Rice Intensification (SRI), originated in Madagascar in the 1980s and has been considered as one of the most promising management techniques that also reduce agricultural water use in addition to reducing GHG emissions. In terms of yields, the practice has maintained, and sometimes even increased, rice yields. While most of the data on methane emission from rice production is from Asian countries, these practices may hold promise in terms of water and fertilizer use efficiency for Madagascar as well.[13] Policy and financing incentives that reward adoption of low-emission practices could open the door to new sources of climate finance including carbon finance. The bilateral agreement between Ghana and Switzerland on Internationally Transferred Mitigation Outcome (ITMO)[14] to purchase carbon credits from emission reductions from rice cultivation is an example (UNDP 2022).

[13] Some CSA practices may be more suited to certain types of rice cultivation than others. For instance, in lowland stepped rice fields in Madagascar, the supply of irrigation water to the rice fields is cascading, meaning that a rice field receives the excess water from the one above. Given the added difficulty of controlling water supply to individual rice plots, such practices may be less suitable.

[14] An ITMO is a unit of emission reduction that can be traded between countries under the framework of the Paris Agreement. ITMOs are part of the cooperative approaches outlined in Article 6.2 of the Paris Agreement, which allow countries to work together to achieve their Nationally Determined Contributions (NDCs) through the transfer of mitigation outcomes.

E. Conclusion

23. While rice production in Madagascar has lagged its population needs over the past decades, there is potential for the country to meet its rice needs. This paper has shown that local rice supply displays positive price elasticity, rising significantly when rice price increases, albeit with several years lag. However, policies resulting in higher rice prices, including import tariffs or VAT increases, may erode consumer welfare in Madagascar, given the inelasticity of rice demand. As such, those policies must carefully weigh their impact on local production and local food prices. In contrast, supply-side policies aimed at increasing the productivity of local rice farmers could raise local rice production without a spike in rice prices. As this paper has shown, rice yields in Madagascar are far below their potential and under the right input conditions, could be substantially improved and allow the country to meet its self-sufficiency goals.

24. Even with improvements in local rice production, Madagascar's rice self-sufficiency goal may be hampered by other factors including poor market access and storage, as well as natural disasters. While measures to raise the productivity of local rice production should be undertaken, there are other non-productivity related constraints that require attention. Of particular concern is poor transport infrastructure, which severely limits the market access of rice producers, hence disincentivizing investments to raise productivity and preventing rice producers from meeting rice demand. Moreover, while agricultural best practices could raise local rice production despite climate change, idiosyncratic natural disaster shocks including cyclones, drought, and locust infestations, would still pose significant risks. Improvements to the transport and storage of rice buffer stocks (procured locally or abroad) would help Madagascar to tackle these challenges.

25. While the country aims to reach rice self-sufficiency by 2027, the environmental and socio-economic impacts of proposed measures should be carefully studied. Where possible, CSA practices that concurrently improve rice yields, climate resilience and limit the negative environmental impact of rice cultivation should be adopted. In addition, while the planting of hybrid rice seeds is a key prong of the authorities' rice self-sufficiency strategy, further studies on the efficacy and unintended effects of hybrid rice adoption are needed.[15] Given the elevated cost of procuring hybrid rice seeds, their greater need for chemical fertilizers, and the lack of studies comparing the performance of hybrid rice seeds to local rice varieties under comparable input conditions, more research should be conducted before the use of hybrid rice seeds is scaled up. Attention should also be paid to the emergence of a rice monoculture, which could erode the resilience of Madagascar's rice production. Lastly, the goal of rice self-sufficiency should not be viewed in silos but instead be balanced against other considerations, including macro-economic, fiscal, and environmental sustainability.

[15] At the start of 2025, the World Bank, in collaboration with the FAO, the Rice+ Project will install field schools in the Alaotra Mangoro Region to compare the performance of the hybrid rice with that of high-yielding local varieties, at various levels of organic and chemical fertilizations. Farmers in the region will then be invited to these field schools to choose the rice variety and the cultivation method best suited to their farms.

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