Sustainable Intensification of Food Crop Production in the Inland Tropical Wetlands

Intensifikasi Berkelanjutan Produksi Tanaman Pangan di Lahan Lebak Tropis

Benyamin Lakitan[1,2 *)]
[1]College of Agriculture, Universitas Sriwijaya, Inderalaya 30662, Indonesia
[2]Research Center for Sub-optimal Lands (PUR-PLSO), Universitas Sriwijaya, Palembang 30139, Indonesia
[*)]Penulis untuk korespondensi: blakitan60@gmail.com

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ABSTRACT

The need to increase food production at the global, national, and local levels should be continued in line with the increase in population. The inability of a country to meet its food needs will directly impact the country's dependence on imports from other countries. This will be a serious problem if the spike in food prices occurs again with a higher intensity and longer period. The efforts to increase food production today, especially in the future, will be increasingly difficult. The main challenge to increase food production is that the availability of agricultural land tends to decline due to conversion for the benefit of various other economic sectors. Indeed, the current technology is ready to produce food without using land, but the production costs are still too expensive compared to conventional crop cultivation which relies on land availability. The next challenge in efforts to increase food production is the necessity to ensure that the cultivation process does not reduce the quality of ecological functions, let alone damage the environment, so that food production can be sustainable. Currently, in addition to economic and ecological considerations, the food production process is also expected to be inclusive, i.e., providing opportunities for the majority of smallholder farmers and rural communities to participate. The social dimension in food production should not be ignored. The problem of increasing food production will become more complex. The dominant technical-agronomic solutions carried out today have proven ineffective and sometimes generate new problems. As a wiser but challenging alternative is to employ the principle of sustainable intensification in food production. So far, the tropical wetlands have not been intensively utilized in Indonesia. It is time for the wetlands to be managed intensively, ecologically, and inclusively.

Keywords: food deficit, import dependence, price spikes, land shrinkage, smallholder farmers

ABSTRAK

Produksi pangan pada tingkat global, nasional, maupun lokal terus perlu ditingkatkan seiring dengan pertambahan jumlah penduduk. Ketidakmampuan suatu negara untuk memenuhi kebutuhan pangannya akan langsung berdampak pada ketergantungan negara tersebut pada impor dari negara lain. Hal ini akan menjadi masalah serius jika lonjakan harga bahan pangan terjadi lagi dengan intensitas dan periode yang lebih lama. Persoalannya, upaya untuk meningkatkan produksi pangan saat ini, apalagi di masa yang akan datang, akan semakin sulit dilakukan. Tantangan utama untuk meningkatkan produksi pangan adalah ketersediaan lahan pertanian cenderung terus menurun akibat dikonversi untuk kepentingan berbagai sektor perekonomian lainnya. Memang teknologi saat ini sudah siap untuk memproduksi pangan dengan tanpa menggunakan lahan, tetapi biaya produksinya masih terlalu mahal dibandingkan dengan budidaya tanaman secara konvensional yang bertumpu pada ketersediaan lahan. Tantangan berikutnya dalam upaya meningkatkan produksi pangan adalah keharusan untuk menjamin agar proses budidaya tidak menurunkan kualitas fungsi ekologis, apalagi merusak lingkungan, agar produksi pangan dapat berkelanjutan. Saat ini, selain pertimbangan ekonomi dan ekologi, proses produksi pangan juga diharapkan bersifat inklusif, yakni memberi kesempatan bagi petani kecil yang mayoritas dan masyarakat perdesaan untuk berperan-serta. Dimensi sosial dalam produksi pangan tidak boleh diabaikan. Persoalan peningkatan produksi pangan semakin lama akan semakin kompleks. Solusi teknis-agronomis yang dominan dilakukan saat ini terbukti belum efektif dan kadang melahirkan masalah baru. Sebagai alternatif yang lebih bijak, sekaligus menantang, adalah mewujudkan prinsip intensifikasi berkelanjutan dalam upaya peningkatan produksi pangan termasuk pada lahan basah tropika. Lahan basah Indonesia yang selama ini belum aktif dimanfaatkan, sekarang saatnya untuk dikelola secara intensif, ekologis, dan inklusif.

Kata kunci: defisit pangan, ketergantungan pada impor, lonjakan harga, penyusutan lahan, petani kecil

INTRODUCTION

The condition of food insecurity that has caused food prices to soar sharply has occurred in the last 15 years, specifically in 2008 and 2012-2014 (Figure 1). The increase in the price of staple foodstuffs, which has reached almost 3 times, is a warning that shocked various related parties. The increasing need for food is unlikely to be contained as long as the world's population continues to grow. Another concern is that the availability of land for agricultural cultivation is shrinking, due to the increasing need for land by various economic sectors. This is exacerbated by the fact that the agricultural sector is almost always less competitive with other economic sectors. Global climate change is an additional burden that cannot be ignored. Demands to reduce greenhouse gas emissions due to agricultural activities, pollution of public waters by agrochemicals due to their excessive application in agriculture, decreasing land quality due to polluted waste, erosion of land surfaces due to mismanagement, and perhaps there are many more burdens that cumulatively have to be shouldered by the agricultural sector.

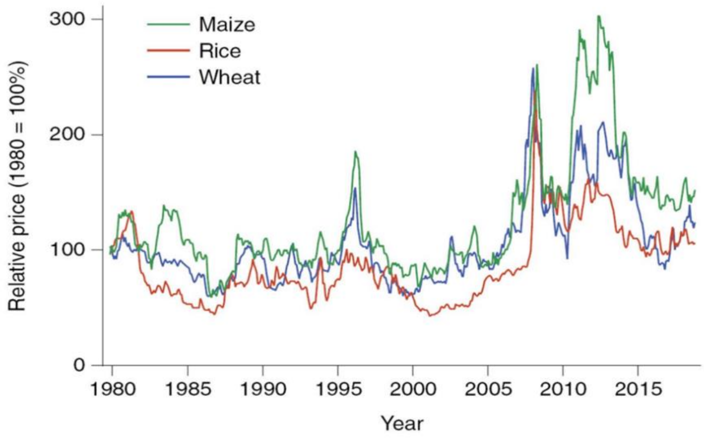

Figure 1. Price trends of the major cereals from 1980–2018 (Cassman & Grassini, 2020)

This is actually a scary mega challenge of this century and the centuries to come. While carrying such a large load, with very complicated complexity, and coupled with many elements of uncertainty, it increasingly appears that the 'monster' that we will faced is the ever-increasing global food needs on the one hand and the diminishing availability of resources and the increasingly limited maneuverability on the other. I do not think anybody can handle the monster, but we can do is doing whatever we can handle.

Let us start with a simple statement and using sustainable intensification as a framework. Sustainable intensification practices are not only to increase productivity but also at the same time to maintain environmental functions so that the food production can last indefinitely. However, Cassman & Grassini (2020) perceived that currently the progress on sustainable intensification actions was slower than expected, but it was necessary to be optimistic that the target can still be realized if development of the relevant technologies was inflexibly prioritized and fully supported by conducive policies and regulations.

The threat of global food deficiencies is real, so it urgently needs to be addressed from now on. Public awareness of the food problems that are being faced and will be increasingly difficult to overcome in the future, needs to be increased. The participation of all parties is urgently needed in dealing with this most important problem. Small steps, real actions of all individuals are more important compared to super comprehensive mega conceptions that are not being implemented. This collective effort can start anywhere, individually, in groups, or organized within an institution; but then again, should not be just a discourse.

Global Trends on the Sustainable Intensification in Agriculture

Although conceptually the sustainable intensification is possible to be formulated and many related documents have been available; nevertheless, their implementations have not yet been fully realized. Xie et al. (2019) mentioned that the main pressure of increasing agricultural production was population growth. The main approach in increasing crop production is to reduce the yield gap between current levels of productivity and targeted potential yields, through effective resource management and adopting relevant technologies and practices that prioritize sustainability in agricultural production systems. These efforts need to be implemented based on local conditions and provide incentives for farmers who do so. Result of Silva et al. (2022) study disclosed that the yield gap in Indonesia was mostly attributed to low efficiency and/or inadequate use of relevant technology. Furthermore, yield response curves to nitrogen application on farmer field data, suggested that it was possible to reduce the application of nitrogen while still increased rice yield i.e., more output with less inputs. Conceptual hierarchy of the yield gaps was presented in Figure 2.

Sustainable intensification requires real action at the operational level. Pretty et al. (2018) suggesting integrating various types of technical practices in agricultural production systems in order to streamline sustainable intensification, create agricultural knowledge economies, and establish policy measures to scale sustainable intensification further. The technical practices included integrated pest management, conservation agriculture, integrated crop and biodiversity, pasture and forage management, irrigation management, etc. Kuyah et al. (2021) recognized some specific key agronomic innovations widely promoted in sub-Saharan Africa, including agroforestry management, cereal-legume intercropping, conservation agriculture, doubled-up legume cropping, fertilizer micro-dosing, and planting basins. Castellano et al. (2019) outlined a sustainable intensification of drainage systems for mitigating nutrient losses, increasing fertilizer nitrogen-use efficiency, and reducing greenhouse-gas emissions. Vanlauwe et al. (2019) reported the full potential of legumes to the sustainable intensification of smallholder farming systems.

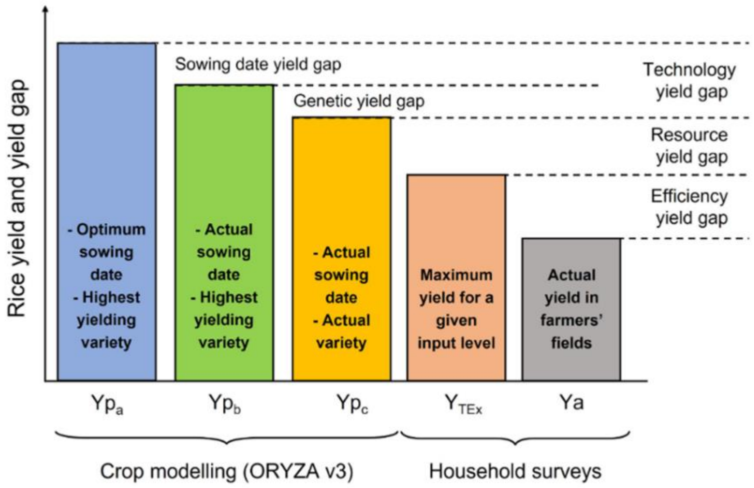

Figure 2. The hierarchy of yield levels and yield gaps in assessing probable additional increase in rice yield (Silva et al., 2022)

There were many more conservation agriculture practices that provide benefits. For instance, zero tillage with residue retention had a mean yield advantage of 5.8%, a water use efficiency increases of 12.6%, an increase in net economic return of 25.9%, and a reduction of 12–33% in global warming potential. The benefits were more-favorable on loamy soils and in maize–wheat cultivation systems (Jat et al., 2020). Nevertheless, it is worth remembering that the choice of the conservation cultivation practices needs to be suitable with the agroecological characteristics of the targeted location.

Ecosystem services not only maintain soil-food-climate security but also make a door for achieving the goal of sustainable development. However, overexploitation, deforestation, faulty land use practices, unsustainable land management, intensive agriculture, high synthetic inputs, etc. disturb our pathway of natural ecosystem by affecting resources and its depletions. The FAO mentioned that every year around 6.5 Mha (million hectare) areas of tropical forest are converted into agricultural land due to rising populations and human needs that affects the natural resources by depriving health, quality, and quantity of other resources such as forest trees, wild animals, soil quality, etc. Degraded land areas were contributed of water erosion, acidification, flooding, wind erosion, and salinity (Raj et al., 2021).

The trajectory of global food self-sufficiency is likely to decline despite increased of food production since projected food demand exceeds potential production. However, under a sustainability scenario, Beltran-Peña et al. (2020) estimated that there would be enough food to feed the global population. Yet, most countries in Africa and the Middle East would continue to be heavily reliant on imports. Yuan et al. (2021) argued that efforts to achieve high yields and high resource-use efficiencies are not a conflicting goal. For instance, current total rice production could be increased by 32% by focusing on filling the yield gap and/or increasing efficiency in the use of available resources.

Resource conservation and its management are having prime importance due to their uncountable contributions in national and international sustainable-based development along with addressing environmental sustainability. In this context, the practices of ecology-oriented and sustainable intensification become good strategies for the conservation and management of natural resources. Contrary to intensive agriculture, the characteristics, principles, and practices of both ecological and sustainable intensification are much clear. These practices will ensure soil-food-climate security along with the maintenance of environmental sustainability and ecological stability (Raj et al., 2021).

The challenge in recent crop cultivation is balancing efforts to increase crop yields and at the same time also maintain the sustainability of environmental functions and provide opportunities for farmers to improve their livelihood. Agronomically, it can increase production so that food demands can be met. Ecologically, it does not damage the environment so that agricultural resources can be managed sustainably. Socially, it is inclusive so that the local communities always have the opportunity to participate. Economically, it can fulfill a better quality of life for farmers.

Sustainable Intensification in the Tropical Wetlands

The area of wetlands including peatlands in the tropics is estimated to account for about 3 percent of the total land on the earth's surface, which is equivalent to 26.9 million km^2. However, it contains soil organic carbon (SOC) at about a quarter of the world's total SOCs. The accumulation of peat in these wetlands occurs due to the slow decomposition process of organic matter due to submergence in an acidic soil and water conditions (Lorenz & Lal, 2018; Nath & Lal, 2017).

Most of these wetlands have not been intensively managed for crop cultivation. However, the need for food has been constantly increasing due to rapid population growth, increasingly complex economies, and novel industrial uses of agricultural products (Andres & Bhullar, 2016). Therefore, the available wetlands need to be managed intensively and sustainably in order to increase food production. In addition to increasing agronomic yield, specifically Nath & Lal (2017) proposed to also improve the livelihood of farmers through an additional income streams by trading of soil organic carbon credits generated through adoption of conservation agriculture in shoreline zones and promoting fish and duck cultures in conjunction with deep water rice farming. This advice may be effective for certain wetland conditions, but not necessarily for other wetlands that have different physico-chemical characteristics. As is well understood, wetlands have a high diversity, both based on local soil properties and agroclimatological conditions.

Diverse, nature-based solutions such as wetland conservation are often overlooked. Based on their latest study in Ethiopian wetlands, Bekele & Haile (2021) reported an extraordinary capacity in capturing and securing atmospheric carbon, however, their conservation efforts have not attracted enough attention from the stakeholders. Therefore, the efforts were overlooked in the nationwide conservation activities.

Failure to get support from stakeholders may occur if wetland conservation activities are carried out for the sole purpose of preserving environmental functions only. The most basic interest of local communities, namely meeting the food needs of families, also needs attention. The ecological interests of the global community to preserve environmental functions need to be integrated with the interests of local communities to meet their basic needs in order to live a healthy life.

Sarkar et al. (2020) have developed a framework to describe the diverse values of inland wetlands that contribute to the human well-being and wetland health (**Figure 3**). They revealed that the drivers of change that trigger wetland quality degradation are climate change, land use practices, population growth, weak governance and policies, in addition to other anthropogenic activities, such as deforestation and overexploitation of wetland resources. Land use changes such as agricultural intensification and infrastructure development are key direct drivers; while institutional and governance factors are the main indirect drivers that threaten inland wetlands in India and Brazil. Based on the assessment above, they recommended the promotion of community-based conservation practices while adopting sustainable livelihood strategies by the local people for the conservation and wise use of wetlands.

Based on the conceptual model in Figure 3, the triggers of environmental damage in the wetlands can be identified as follows: (a) climate change both globally and partially, especially changes in temperature and rainfall distribution and intensity; (b) changes in land use, including expansion of residential areas, infrastructure development, and land clearing for agriculture; (c) overexploitation of land resources, particularly as a result of deforestation and surface erosion; (d) population growth that directly leads to an increase in food needs, changes in consumption patterns, and changes in the way of food production; and (e) other causes, including the spread of invasive weeds, industrial pollution and excessive agrochemical use, and solid waste pollution.

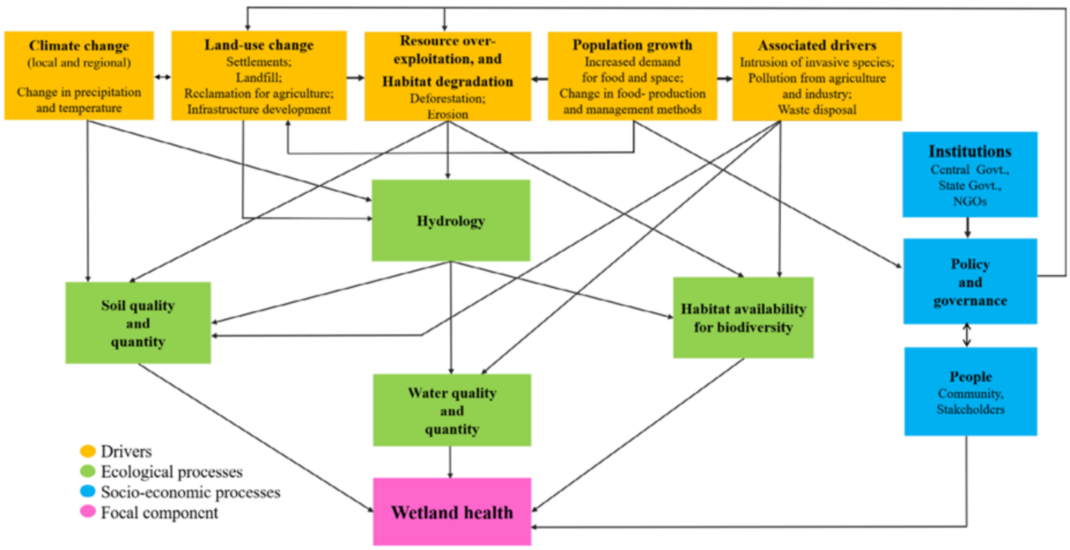

Figure 3. Conceptual model depicting the intricate relationship of wetland health with the different drivers of change (Sarkar et al., 2020)

Furthermore, to restore the ecological function of already degraded wetlands requires real efforts through: (a) management of water resources in accordance with the characteristics of local wetlands and the intensity of their destruction; (b) restoration of soil and water quality and arranging water availability to be optimal to meet the needs of plant, fish and livestock farming; and (c) restoration of biodiversity and increasing land vegetation coverage.

However, ultimately all these carefully designed efforts will only be successful if they have the full support of: (a) responsible government institutions and officials, and relevant non-governmental organizations; (b) conducive and realistic policies and regulations; and (c) the general public and local stakeholders.

Andres & Bhullar (2016) supports the statement on the importance of building an understanding that governance and regulation are an important part of the successful implementation of sustainable intensification in agriculture. In addition, they also suggest that the integration of policy priorities and research priorities is designed to produce relevant and effective policies and regulations. These integration forces are associated with increased incomes of smallholder farmers, social welfare, healthy living, quality of the local environment, readiness to face climate change, resilience to climate extremes, food security, and moderated price instability (Figure 4).

Tropical wetlands are ecosystems rich in biodiversity, so they are important to the world and have socioeconomic value that is also important for the surrounding communities. However, tropical wetlands are often used as resources for exploitation, among other things by being drained and converted to other uses (Sarkar et al., 2020). This wetland conversion often triggers degradation of these lands and increases greenhouse gas emissions, especially carbon dioxide (CO_2) due to peat oxidation and biogenic methane (CH_4). The utilization of soil organic carbon for agriculture released significant amounts of CO_2. Cumulative net emissions from global peatland use were estimated at 6 Pg [1] carbon for the period 1850-2015. Wetlands contributed to about 30% of total CH_4 emissions and were expected to continuously increase as climate change progresses (Lorenz & Lal, 2018).

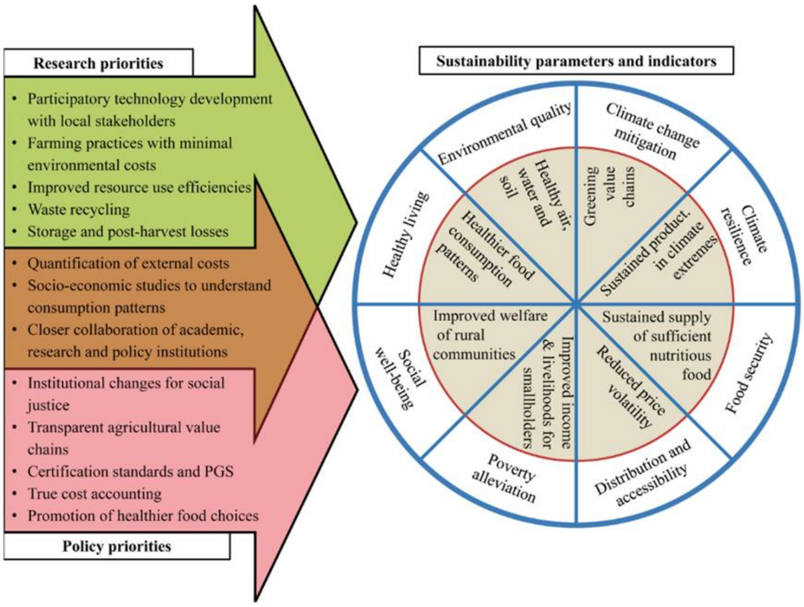

Figure 4. Research and policy priorities for sustainable intensification in agriculture (Andres & Bhullar, 2016)

Sustainable intensification must create a balance between efforts to increase crop productivity and to minimize negative impact on the environment. The efforts should cover water and land resource management systems, productive and environmentally friendly crop cultivation systems, and breeding systems to produce high-yielding varieties and adaptive to tropical wetland agroclimatology.

Lorenz & Lal (2018) believes that the paludiculture system is suitable for crop cultivation in wetlands because it provides additional benefits in the form of carbon sequestration. Tan et al. (2021) loosely conceptualized the paludiculture as a biomass production system on wet peatlands with the potential to maintain carbon storage; therefore, substantially limiting emission of greenhouse gases. This system was recognized

[1] 1 petagram (Pg) = 1 billion metric ton = 10^{12} kg

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as a sustainable, non-drainage-based agriculture in the peatland areas. Abendroth et al. (2022) proposed the use of subsurface tile drainage systems, namely saturated buffers, controlled drainage, and drainage water recycling, as the conservational practices by using vegetation and/or infrastructure to reduce water and nutrients losses in wetland ecosystems. The subsurface drainage was suitable during dry season in wetland areas.

Campbell et al. (2014) asserted that climate smart agriculture (CSA) was complementary to sustainable intensification (SI). Continuous intensification included adaptation efforts to climate change, to reduce greenhouse gas emissions per unit of crop yield. Yet, adaptation was not only limited to climate change, but also included several other related aspects, namely all aspects that contribute to the success of wetland management, including diversification of agricultural cultivation systems, adaptation planning at the local level, building responsive governance systems, improving leadership skills, and building asset diversity.

Progress on Sustainable Intensification in the Indonesian Inland Wetlands

Although there is plenty of available information that can be used as references in realizing sustainable intensification of agricultural cultivation in the wetlands, but since characteristics of the wetlands are also very diverse, the wetland management design must still be based on the reality of local and current conditions, including: (a) land geomorphology and soil physico-chemistry; (b) dynamics of waterlogging patterns caused by the distribution and intensity of rain, not only at local sites but also in the rain catchment areas; (c) the socio-economic capacities and preferences of local communities; (d) local wisdom values that are still exercised by local communities; and (e) technology adoption capacity of the local agricultural actors. Although intensive and sustainable agricultural cultivation practices are open to all parties (inclusive), the early initiation should be focused on the reality of the land physical condition, water dynamics, and socio-economic status of the local community.

An agronomic-heavy framework has been applied to develop wetlands in order to increase food production, which includes (a) land characterization and development issues; (b) analysis of historical developments and lessons learned; (c) technology development; and (d) optimization of development. (Sulaiman et al., 2019). The framework may be ecologically unsustainable and financially unprofitable for smallholder farmers because it is partial in nature, does not focus on the specific characteristics of the targeted wetlands, and does not recognize the complexity of the real problem. Results Beltran-Peña et al. (2020) study indicated that Indonesia's position in the global self-sufficiency ratio is better if Indonesia adopted the sustainability scenario in the 21st century (Figure 5).

Our previous study had identified the main challenges in increasing productivity and cropping intensity on the inland wetland in South Sumatra, Indonesia which included: (1) unpredictable flooding occurrences and low soil nutrients content (agronomic constraint), (2) low financial and technology adoption capacities of local farmers (economic constraint), and (3) public policy and regulation had not significantly escalated farmer's motivation to increase food production (social and institutional constraints). Results of this research suggested multidimensional (technical, financial, ecological, and socio-cultural) approaches should be integrated in collective efforts for sustainably intensifying food production on the inland wetland (Lakitan et al., 2019). The inhibiting and driving factors on enhancing rice productivity (Figure 6).

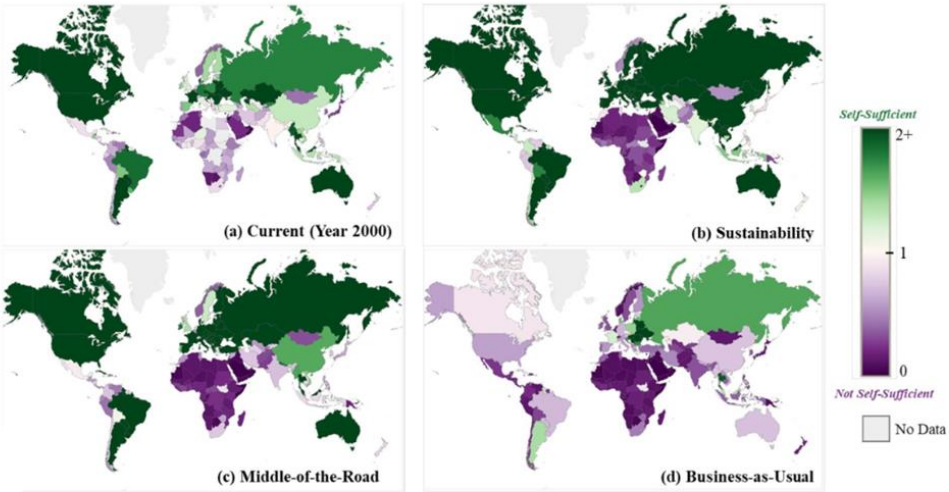

Figure 5. Global self-sufficiency ratios in the 21st century. This figure displays: (a) base data on self-sufficiency ratio in 2000 and the projected ratio in 2100 under different scenarios, i.e., (b) sustainability, (c) middle-of-the-road, and (d) business-as-usual (Beltran-Peña et al., 2020)

The rigorous challenges in practicing sustainable intensification in rice cultivation in inland wetlands are (a) the decreasing of available land area due to the conversion of land functions to non-agricultural use while needs for food continue to increase in line with the rate of population growth; (b) the difficulty on predicting when the rice growing season may begin due to the erratic behavior of waterlogging in each year; (c) the expensive cost of crop production and sometimes the cost is higher than the additional income derived from the increase in crop yields; (d) the low and fluctuating commodity prices at harvest; and (e) the temptation to quit employment as a farmer for economic reasons and/or social status.

It is almost impossible for hundreds of small farmers to unite to build polders communally. Polders are needed so that water can be managed year-round in a whole expanse of land surrounded by embankments higher than the water level at the time of the highest inundation. Without the help of polder system infrastructure, wetland farmers only grow rice once a year. Only farmers with land that is only shallowly flooded and in such a short period have the opportunity to grow rice twice a year (Figure 7).

At present, intensity of agricultural activities on inland wetland was low mainly due to two unfavorable extremes, i.e., unpredictable occurrence of flooding during rainy season and drought during dry season. Relevant, affordable, and acceptable technologies are required as solution to this problems. The technologies should be developed based on actual needs, preferences, and absorptive capacity of smallholder farmers, to ensure adoption. Moreover, government intervention is expected to build water management

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infrastructure in tropical riparian wetlands, specifically by developing polder systems (Lakitan et al., 2018).

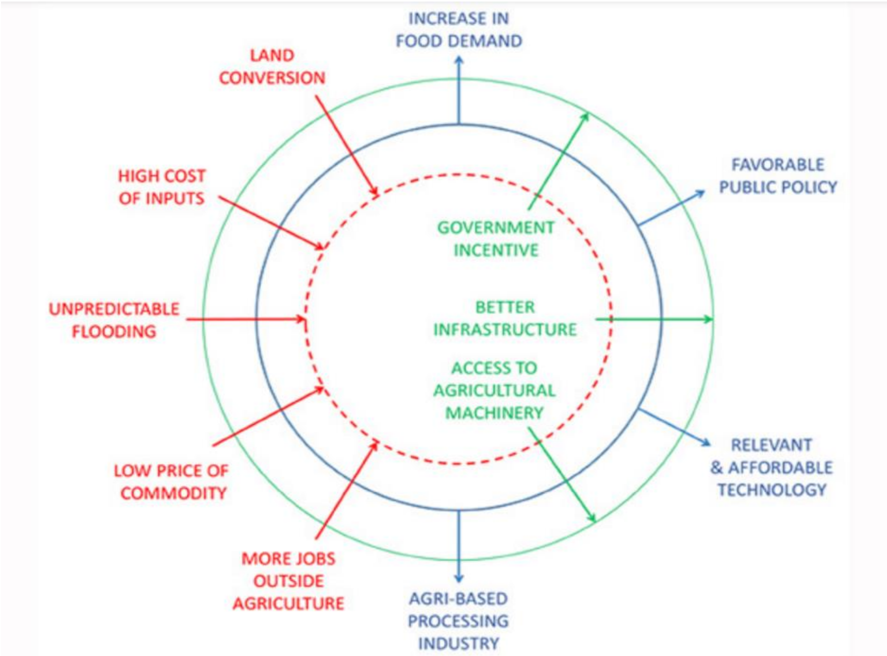

Figure 6. Factors causing shrinkage (red) and enlargement (green and blue) of crop cultivation activities at inland wetlands in Indonesia (Lakitan et al., 2019)

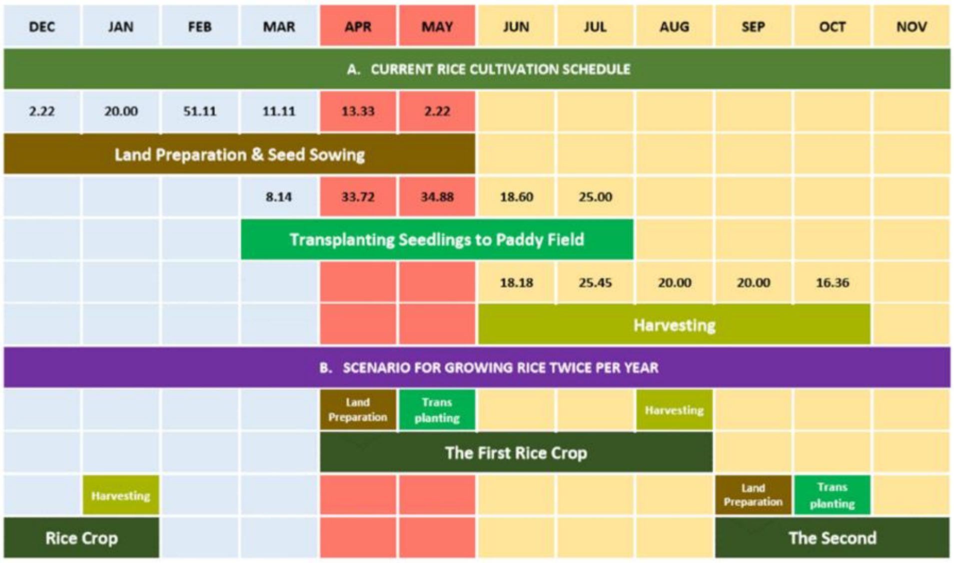

Figure 7. Current rice cultivation schedule and scenario for growing rice twice annually at riparian wetlands (Lakitan et al., 2018)

REFERENCES

Abendroth LJ, Chighladze G, Frankenberger JR, Bowling LC, Helmers MJ, Herzmann DE, Youssef M. 2022. Paired field and water measurements from drainage management practices in row-crop agriculture. *Scientific Data*. 9 (1): 1-13. DOI: 10.1038/s41597-022-01358-7.

Andres C, Bhullar GS. 2016. Sustainable intensification of tropical agro-ecosystems: need and potentials. *Frontiers in Environmental Science*. 4: 5. DOI: 10.3389/fenvs.2016.00005.

Bekele T, Haile Y. 2021. Intensification of climate change mitigation and adaptation actions through wetland conservation: the case of Ethiopian freshwater wetlands. *Geology, Ecology, and Landscapes*. 1-6. DOI: 10.1080/24749508.2021.1923271.

Beltran-Peña A, Rosa L, D'Odorico P. 2020. Global food self-sufficiency in the 21st century under sustainable intensification of agriculture. *Environmental Research Letters*. 15 (9): 095004. DOI: 10.1088/1748-9326/ab9388.

Campbell BM, Thornton P, Zougmoré R, Van Asten P, Lipper L. 2014. Sustainable intensification: What is its role in climate smart agriculture? Current Opinion in *Environmental Sustainability*. *8*: 39-43. DOI: 10.1016/j.cosust.2014.07.002

Cassman KG, Grassini, P. 2020. A global perspective on sustainable intensification research. *Nature Sustainability*. 3 (4): 262-268. DOI: 10.1038/s41893-020-0507-8.

Castellano MJ, Archontoulis SV, Helmers MJ, Poffenbarger HJ, Six J. 2019. Sustainable intensification of agricultural drainage. *Nature Sustainability*. 2 (10): 914-921. DOI: 10.1038/s41893-019-0393-0.

Jat ML, Chakraborty D, Ladha JK, Rana DS, Gathala MK, McDonald A, Gerard B. 2020. Conservation agriculture for sustainable intensification in South Asia. *Nature Sustainability*. 3(4): 336-343. DOI: 10.1038/s41893-020-0500-2.

Kuyah S, Sileshi GW, Nkurunziza L, Chirinda N, Ndayisaba PC, Dimobe K, Öborn I. 2021. Innovative agronomic practices for sustainable intensification in sub-Saharan Africa. A review. *Agronomy for Sustainable Development.* 41 (2): 1-21. DOI: 10.1007/s13593-021-00673-4.

Lakitan B, Hadi B, Herlinda S, Siaga E, Widuri LI, Kartika K, Meihana M. 2018. Recognizing farmers' practices and constraints for intensifying rice production at Riparian Wetlands in Indonesia. *NJAS-Wageningen Journal of Life Sciences*. 85: 10-20. DOI: 10.1016/j.njas.2018.05.004.

Lakitan B, Lindiana L, Widuri LI, Kartika K, Siaga E, Meihana M, Wijaya A. 2019. Inclusive and Ecologically-Sound Food Crop Cultivation at Tropical Non-Tidal Wetlands in Indonesia. *AGRIVITA, Journal of Agricultural Science*. 41 (1): 23-31. DOI: 10.17503/agrivita.v40i0.1717.

Lorenz K, Lal R. 2018. Carbon Sequestration in Wetland Soils. In: Carbon Sequestration in Agricultural Ecosystems. *Springer, Cham.* DOI: 10.1007/978-3-319-92318-5_5.

Nath AJ, Lal R. 2017. Managing tropical wetlands for advancing global rice production: Implications for land-use management. *Land Use Policy*. 68: 681-685. DOI: 10.1016/j.landusepol.2017.08.026

Pretty J, Benton TG, Bharucha ZP, Dicks LV, Flora CB, Godfray HCJ, Wratten S. 2018. Global assessment of agricultural system redesign for sustainable intensification. *Nature Sustainability*. 1 (8): 441-446. DOI: 10.1038/s41893-018-0114-0.

Raj A, Jhariya MK, Khan N, Banerjee A, Meena RS, Rani K. 2021. Resource Conservation for Sustainable Development. In Sustainable Intensification for Agroecosystem Services and Management (pp. 457-492). *Springer, Singapore*. DOI: 10.1007/978-981-16-3207-5_14.

Sarkar P, Salami M, Githiora Y, Vieira R, Navarro A, Clavijo D, Padgurschi M. 2020. A conceptual model to understand the drivers of change in tropical wetlands: a comparative assessment in India and Brazil. *Biota Neotropica*. 20(suppl. 1): e20190913. DOI: 10.1590/1676-0611-BN-2019-0913.

Silva JV, Pede VO, Radanielson AM, Kodama W, Duarte A, Annalyn H, Stuart AM. 2022. Revisiting yield gaps and the scope for sustainable intensification for irrigated lowland rice in Southeast Asia. *Agricultural Systems*. 198: 103383. DOI: 10.1016/j.agsy.2022.103383.

Sulaiman AA, Sulaeman Y, Minasny B. 2019. A framework for the development of wetland for agricultural use in Indonesia. *Resources.* 8 (1): 34. DOI: 10.3390/resources8010034.

Tan ZD, Lupascu M, Wijedasa LS. 2021. Paludiculture as a sustainable land use alternative for tropical peatlands: A review. *Science of the Total Environment*. 753: e142111. DOI: 10.1016/j.scitotenv.2020.142111.

Vanlauwe B, Hungria M, Kanampiu F, Giller KE. 2019. The role of legumes in the sustainable intensification of African smallholder agriculture: Lessons learnt and challenges for the future. *Agriculture, ecosystems & environment*. 284: 106583. DOI: 10.1016/j.agee.2019.106583.

Xie H, Huang Y, Chen Q, Zhang Y, Wu Q. 2019. Prospects for agricultural sustainable intensification: *a review of research. Land*. 8 (11): 157. DOI: 10.3390/land8110157.

Yuan S, Linquist BA, Wilson LT, Cassman KG, Stuart AM, Pede V, Grassini P. 2021. Sustainable intensification for a larger global rice bowl. *Nature communications*. 12 (1): 1-11. DOI: 10.1038/s41467-021-27424-z.