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Analysing agricultural policy outcomes in the uplands of Indonesia: A multi-dimensional sustainability assessment

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Abstract

A wide range of holistic frameworks are used to assess the sustainability of agricultural policies and programs, but much of the existing research tends to overlook the socio-cultural and governance dimensions of sustainability. This article aims to address those gaps by comprehensively assessing the environmental, economic, social, and political dimensions of sustainability. We use a case study of irrigation policies for agricultural expansion that target the Pagar Alam upland region in Indonesia. The assessment reveals opportunities and threats from the policy that affect the sustainability of upland landscapes and communities. By overly focusing on productivity goals while ignoring other sustainability criteria, the policy generates risks that threaten existing sustainable development pathways. To achieve positive policy outcomes, Indonesia needs to reconcile its national food production goal with local development goals. Lastly, to optimise policy outcomes, agri-sustainability research should apply comprehensive approaches that simultaneously address multiple sustainability dimensions.

KEYWORDS
agriculture, irrigation, reservoir, sustainability assessment, uplands

1 | INTRODUCTION

Sustainable agriculture remains a core issue for the international development community. Like most Southeast Asian countries, Indonesia adopted United Nations Resolution 70/1, committing the country to achieve the sustainable development goals (SDGs) by 2030. Recent research, however, suggests a significant gap between Indonesia's aspirations and the applications of its programs and policies intended to deliver the development outcomes necessary to reach the SDGs (Leimona et al., 2015; Nasrullah, 2022). A more holistic approach to designing policies and programs could support efforts in Indonesia to close the gap between aspirations and outcomes.

Among the key obstacles to meeting SDG goals is the inconsistency among policies across socio-economic and environmental sectors. Agricultural policies often work in siloes, without enough consideration of the consequences across sectors and scales (Neely et al., 2017). For example, attempts to establish food and agricultural policies often result in negative consequences of deforestation and environmental degradation (Sonnino et al., 2014; Tilman et al., 2002). This is frequently the case in Indonesia where food security strategy is largely focused on increasing the production of rice, the major source of calories for most households.

Rice is the centre-piece of food security in Indonesia and rice polices are guided by self-sufficiency targets supported with price stabilisation measures, a "rice for the poor" program, fertiliser and input subsidies, and expanded reservoir construction for irrigation (Octania, 2021; Reardon et al., 2015). In upland landscapes, these production-oriented agricultural policies encourage land use practises that result in soil erosion and nutrient loss, deforestation, flooding, landslides, sedimentation and biodiversity loss (Leimona et al., 2015;

Quincieu, 2015). Policies designed to meet production targets for achieving food security too often ignore the many essential goods and services that upland agro-ecosystems can provide, including watershed protection, soil conservation, biodiversity and carbon sequestration, as well as alternative livelihood pathways and cultural attributes (Clough et al., 2016; Tilman et al., 2002).

To meet SDGs, policy design and implementation are challenged to integrate the needs of local communities with national interests. Indonesia has a long history of implementing national agricultural policies that pose uniform solutions across diverse upland landscapes and communities (Armitage, 2004; Belsky, 1994). Similarly, environmental policies have tendencies to pursue national goals without consideration of local socio-economic characteristics, social networks or capacities of targeted farm households (Li, 2002; Peluso, 1993).

A lack of local acceptance of national policies may result when the interests and welfare of farm households and communities, with limited options and capacities to find alternatives for their subsistence, differ from national priorities (Li, 2002; Vel et al., 2016). For that reason, consultation with those who may be poorly served by the national priorities is essential to ensure policy can generate positive outcomes for local livelihoods (Bardsley, 2015; Vel et al., 2016). Comprehensive assessments to understand the synergies and contradictions between national development goals and local development aspirations can help to encourage policy acceptance and strengthen sustainability outcomes (Sonnino et al., 2014).

Using a case study approach, this paper argues that national strategies and policies to balance sustainability goals between local and national interests require a comprehensive understanding of multiple sustainability dimensions at different scales. The case study presented here assesses the sustainability of a national-level irrigation reservoir (IR) policy to support irrigated rice expansion that targets farming communities in Pagar Alam, a forested upland landscape in South Sumatra, Indonesia. The upland areas of Indonesia play an important role supporting economic, environmental, and social goals by generating various ecosystem services from the complex land use mosaics (Hadi & van Noordwijk, 2005). To help achieve national food security targets, the government is constructing the reservoir along the forest border in Pagar Alam, with the goal of expanding the local irrigated rice production system.

This article assesses the potential gap in achieving agricultural sustainability through IR policy through a comprehensive assessment approach. The study applies the multi-dimensional assessment as suggested in the Sustainability Assessment of Food and Agricultural Systems (SAFA) framework by the Food and Agricultural Organisation of the United Nations (FAO, 2014a). The SAFA includes environmental, economic, social, and political dimensions. The bottom-up, integrated assessment incorporates primary data from farm households, with secondary data from government statistics and policy documents.

This study demonstrates a comprehensive and rapid review of the potential sustainability outcomes of the IR policy, by using the results of the household survey, interviews, observations, and reviews of the policy documents. The descriptive quantitative and qualitative methods are utilised to analyse the opportunities and threats introduced by the IR policy specifically focused on achieving rice production target. This approach provides an alternative approach for policymakers and sustainability researchers to assess the sustainability outcomes of the agricultural policies and programs.

1.1 | Sustainability assessments of agricultural policies

Sustainable agriculture includes activities that meet the needs of present and future generations for its products and services while ensuring profitability, environmental health, and social and economic equity (FAO, 2022). Policy that promotes sustainability within those three dimensions is necessary to enhance transformation in food systems and achieve food security goals (Sonnino et al., 2014). Due to the sectorial nature of policy-making, national-level agricultural policy often focuses solely on one or two dimensions, to the detriment of other elements. (Lang & Barling, 2012). A partial approach often loses sight of the long-term policy outcomes for local people and landscapes, potentially threatening sustainability (Bardsley & Knierim, 2020).

Numerous studies highlight the importance of implementing a multidimensional assessment of agricultural sustainability, comprising economic, environmental and social dimensions (Lang & Barling, 2012), as well as the political dimension (FAO, 2014a). To date, at least 200 frameworks are available to assess agricultural sustainability for policy and research (FAO, 2014b). Those frameworks are diverse in theoretical, spatial, and temporal concerns. Many of the frameworks utilise indicators to measure and compare agricultural sustainability from the global to farm scales, with different purposes and priorities (Tello & González de Molina, 2017).

The literature compares and classifies the different agricultural sustainability assessment methods. Talukder and Blay-Palmer (2017) review eight comprehensive frameworks, finding that each methodology has some specificity related to the purpose of assessment, which varies in terms of the theoretical, spatial, and temporal concerns. Alaoui et al. (2022) reviewed the strengths and weaknesses of six holistic assessment frameworks and found that each indicator has different suitability with regards to the time and data requirements, accuracy, scale, and the targeted sector. Many assessment frameworks focus on particular dimensions of sustainability but do not comprehensively consider all three dimensions (Alaoui et al., 2022). The complexity of the agricultural systems makes comprehensive agri-sustainability assessments challenging to conduct.

A recent review of 1289 scholarly articles on agricultural sustainability assessment identified that a large quantity of research overlooks the socio-cultural (43% of the articles) and governance (67% of the article) dimensions of sustainability (El Bilali et al., 2021). Socio-cultural and governance elements relate to people, society, and the institutions that shape people's actions towards policy. Some of the social sustainability elements include cultural attributes, identity, values and norms, and collective actions (Di Iacovo, 2014). The social dimension is central to achieving agricultural sustainability, because if the policy does not match local social and cultural aspirations, positive outcomes will be challenging to achieve or fail to meet local people's needs (Janker et al., 2019; Schaafsma et al., 2022). Governance-related studies

tend to be conducted in developed countries, such as the EU, Australia, Japan, and USA, and largely focus on the policy transformation of urban agri-food supply chains (El Bilali et al., 2021).

Multi-dimensional sustainability assessments in rural developing countries are still under-represented in the literature (El Bilali et al., 2021). This study aims to partly address this gap, by exemplifying how the social and political dimensions of sustainability can be analysed, with a focus on IR policy in the rural uplands of Indonesia. Ideally, sustainability assessment frameworks should provide comparable results between places, but also be sufficiently flexible to represent the site-specific characteristics of agroecological systems. Some authors are particularly concerned about the comparability of assessment results (Song et al., 2020; Talukder et al., 2018; Talukder & Blay-Palmer, 2017), with Schader et al. (2014) finding that there are often trade-offs between the scope and precision of assessment research, with inconsistent indicators and different analytical scales leading to contradictory results.

Others studies contend that site and context-specific assessments are necessary to capture sustainability problems and challenges at multiple scales (Gasparatos et al., 2008; Singh et al., 2019). Binder et al. (2010) reviewed the sustainability assessment approaches and group the frameworks into three categories: (1) top-down; (2) top-down with limited stakeholder participation and (3) bottom-up integrated and transdisciplinary approaches. They assert that a bottom-up integrated approach is the best approach to address the various scales and dimensions of agricultural development. El Bilali et al. (2021) highlight the importance of strengthening the science-policy interface within agricultural sustainability assessment by adopting a multiscalar 4-P (planet, people, profit and policy) approach. Their study utilises the SAFA framework (FAO, 2014a) that adds the political dimension into the triple bottom lines (economic, environmental and social) of sustainability.

This study adopts the bottom-up integrated approach to discuss the impacts of agricultural policy within an upland area in Indonesia. The discussion is informed by the four sustainability dimensions suggested by the SAFA framework to address the gap in the lack of studies that address all sustainability dimensions. The combination of SAFA and the bottom-up integrated approach provides flexibility to discuss policy impacts and trade-offs between sustainability dimensions.

2 | THE CASE STUDY: IRRIGATION RESERVOIR POLICY IN THE UPLANDS

2.1 | Indonesia food security and irrigation reservoir policy

Expanding and modernising irrigation is a top priority for Indonesia. Indonesia has the highest per capita rice consumption in the world and irrigated agriculture holds significant potential to reduce rural poverty while increasing the country's food security (Octania, 2021). Irrigated rice production is essential for national food security (Alaerts, 2020) and irrigation-related farming provides jobs to 21 million households (Mariyono, 2014). A recent World Bank report documents that 60 percent of Indonesia's arable land is irrigated and 85 percent of paddy production is irrigated (World Bank, 2021).

Nawa Cita, the National Development Agenda, highlights Indonesia's vision to achieve the national food security target by improving the production of strategic crops (rice, maize and soybean). Moreover, Indonesia aims to be a rice-exporting country by 2030 (Government of Indonesia, 2021). A key component of national plans to increase crop production involves the construction of 61 new reservoirs to expand irrigation by 2024 (Ditjen, 2018).

The irrigated rice practise is linked to improvements in national production and food security (Mariyono, 2014). Between 2006 and 2017, national rice production increased by 37%, from 52 to 80 million tons, partially driven by improved water security, irrigation area expansion, and related technical support for farm resilience (Alaerts, 2020). However, other factors also contribute to increased rice outputs. For example, Alaerts (2020) highlights that the causality between irrigation and increased productivity varies across locations. Furthermore, a study of rice production dynamics in Indonesia indicates that irrigation is strongly correlated with the harvested area and total output, but only weakly associated with productivity (Panuju et al., 2013).

These results help explain why rice expansion programs are linked to new reservoirs and irrigation networks, but their value for upland production is less certain. Traditional upland rice was cultivated through weather-dependent, low input, low output swidden systems largely for subsistence purposes, which has meant this practise is gradually being abandoned and replaced with cash cropping (Cramb et al., 2009). Although there have been many changes to upland production systems, most are still dependent on rainfall or unsophisticated local irrigation within mixed-farming systems, and reservoirs can provide a secure water supply for irrigation to enhance productivity and encourage further uptake of upland rice-farming. However, IRs in upland areas affect the people and landscape differently from their lowland counterparts, and its potential for sustainable outcomes need to be examined.

2.2 | Study area: Pagar Alam upland landscape

Pagar Alam is a rural upland district in South Sumatra Province where 70% of its population work as farmers (BPS Pagar Alam, 2017). Around one-third of land use is coffee agroforestry (Amaruzaman et al., 2021). Farmers mainly grow Robusta coffee (*Coffea canephora*) mixed with fruits, commercial timber and horticultural crops. Coffee farmers largely use traditional management practises, resulting in low yields and low quality. More recently, private and NGO-led initiatives are engaging with the community to improve access to higher value markets linked to improved post-production practises.

Coffee agroforestry partly replaced local swidden rice farming practises by the late 1970s in Pagar Alam, providing more diverse income sources. By the early 1980s, coffee farming had replaced irrigated rice farms to the extent that the local irrigation system fell into disrepair (Godoy & Bennett, 1988). Since 2010, farmers in Pagar Alam have gradually adopted vegetable farming practises introduced by migrants from West Java. However, most farmers still retain their

coffee agroforest area, and vegetable crops are gradually being adopted as a complementary source of short-term income to perennial coffee. (Table 1)

The new reservoir in Pagar Alam is located on an upstream catchment of Musi Watershed – the largest watershed in South Sumatra. The construction process modified the river to create a large water reservoir through permanent dam structures. The reservoir is located on the border of the protected forest area, where farmers manage coffee agroforestry. The new rice reservoir aims to convert 3000 hectares of coffee agroforestry land to irrigated paddy fields, equivalent to 20% of the existing coffee agroforestry area. Farmers in the designated area will be assisted to convert their agroforest land into irrigated rice fields (*sawah*) through an aligned government technical assistance program.

3 | METHODS

3.1 | Sampling and data collection

This research utilises data from household surveys, interviews, field observation and policy documents. The household survey design included several steps. First, a spatial analysis on Musi Watershed was performed to identify the relevant upper catchments in Pagar Alam, resulting in recognition of three major sub-watersheds in the region (Selangis, Lematang and Basemah). Second, the researchers stratified the 84 villages within the three sub-watersheds based on altitude, primary farming practises, topography, and proportion of area with slopes greater than 15 degrees, with 46 villages matching the criteria. In the final stage, 18 households were chosen to be interviewed from a household census of the 23 randomly sampled villages out of the previously identified 46 villages. At completion of the household survey, 416 heads of farm households were interviewed. The household survey was undertaken from March to April 2019.

The questionnaire consists of household socio-economic and farm characteristics, farmers' attitudes and visions towards farming, intentions to adopt policy, and opinions about the IR. The socio-economic data provides detailed information regarding the demographic and economic characteristics of farm households. The data on farming systems detail the number of plots, tenure and the size and slope of plots. The variable for the rice plots includes the irrigation type and management status.

The survey captured the current land use of each plot at the time of the survey, but also asked the plot uses 5 years before the survey and what farmers thought the plots would be used for 3 years after the survey. The survey also examined the level of respondents' trust when collaborating with their social networks in livelihood activities.

Farmers' attitudes towards farming activities are categorised into three groups: attitudes towards coffee farming, rice farming, and their plans for future crop choices. The survey uses a 5-point Likert scale that ranges from strongly disagree (1) to strongly agree (5), while the intention to farm comprises a yes-no question. Farmers' perception regarding policy is examined through an open-ended question in which the respondents were asked to make a short statement regarding their opinion on the IR policy.

3.2 | Analytical approach

The four SAFA sustainability dimensions (economic, environmental, social and political) are used together, following the integrated-descriptive approach suggested by Binder et al. (2010). The bottom-up integrated and descriptive approach focuses on the assessment at regional and local scales by using a transdisciplinary process, combining stakeholder participation and other evidence-based assessment (Binder et al., 2010). The descriptive statistics and qualitative analysis mainly focus on the threats and opportunities brought by the IR to each sustainability dimension.

For open-ended responses, respondents' statements were coded and presented in a wordcloud format using the web-based wordcloud generator (www.wordclouds.com). The size of the cloud represents the frequency of the elicited opinion. To analyse the political dimensions, we review the agricultural and environmental policies at national, provincial, and local scales.

4 | RESULTS

4.1 | Household socio-economic characteristics

The households in the survey area comprise 77 farm households (18.5%) that produce rice and 337 (81.5%) that did not produce rice in the 12 months prior to the survey. Rice farming households are defined as farm households that owned and/or managed rice fields during the previous one-year period from the survey interview. The majority of rice farmers also grow coffee (94%). The overall average age of all respondents is about 47 years old, and the average formal education is 8 years. On average, rice farmers are slightly older

TABLE 1 Rice production in Pagar Alam and South Sumatra 2010–2021

	Pagar Alam			South Sumatra		
Rice production characteristics	**2010**	**2018**	**2021**	**2010**	**2018**	**2021**
Harvested area (000 ha)	6.1	2.8	2.7	690.2	581.5	496.3
Production (000 ton)	31.8	12.7	14.5	3.041	2.995	2.552
Avg productivity (ton/ha)	5.15	4.8	5.4	4.4	5.14	5.14

Source: BPS Pagar Alam (2017) and BPS Sumatera Selatan (2021).

(2 years) and have one more year of formal education than other farmers.

The average annual income of farm households is around 22.8 million IDR (about $1540 USD), which was mostly provided by coffee farming (55%). Rice farming only represents about 3% of total respondent income. Even for rice farming households, rice production only contributed to 19% of their annual income compared to 44% from coffee farming (Figure 1a). Table 2 and Figure 2 summarise the respondent households socio-economic characteristics.

4.2 | Plot characteristics

Each farm household ($n = 416$) managed 2.3 farm plots per household on average. Rice accounted for around 6% of the total area managed by the 416 households (Table 3). The average plot size (owned and/or managed) per household is 0.88 ha, with the average rice plot size 0.56 ha. The average size of rice fields in Pagar Alam is similar to the national average size of smallholders' rice fields, which is less than 0.5 ha.

About two-thirds (69%) of all respondent plots are coffee agroforest, followed by vegetable crops (12%), while rice fields only represent 9% of respondent plots (Figure 3a). Almost half of the plots (44%) are located on land with slopes greater than 15 degrees, which are less suitable for irrigated rice fields (Figure 3b). Rice farmers tend to have more plots and access to more farm land in comparison to non-rice farmers. Most rice farming households (62%) irrigate from small ponds or collect rainwater in a traditional process called *tebat*. The other 23% irrigate from reservoirs (Figure 3c). Of the 88 rice plots, 37 are owned by and managed by households; 9 plots are owned by households and managed by other farmers; and 41 plots are rented (in some form) from other households. (Figure 3d). Table 3 and Figure 3 summarise the characteristics of respondents' farming plots.

4.3 | Attitudes towards farming

The prevailing attitude towards coffee farming is represented by two statements: 'Coffee is an important farming culture that I want to retain' and 'Coffee is an important cash crop for my family.' From the respondents, more than 90% express agreement with the two statements: 37.5% strongly agree that coffee is their culture that they want to retain; and 49.3% strongly agree that coffee is an important cash crop for their family (Figure 4a). This attitude might be expected as

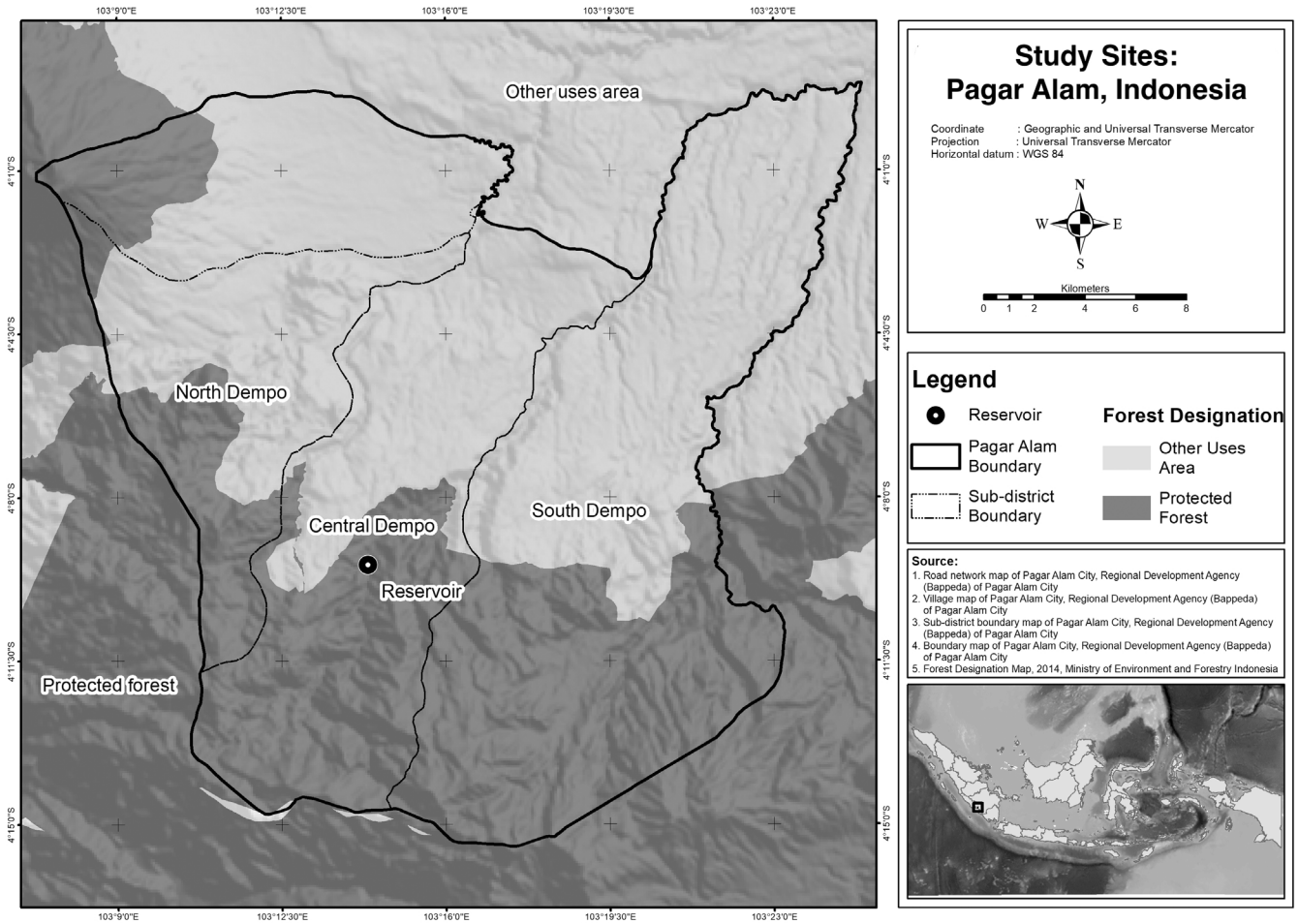

FIGURE 1 Pagar Alam of South Sumatra Province, Indonesia

coffee provides most of the household income for the majority of respondents.

Most households (85%) answered 'agree' and 'strongly agree' that rice-farming will improve their household income, and a similar number (83%) believe that rice-farming does not degrade the environment (Figure 4b). Albeit predominantly coffee farmers, more than half (57%) of respondents agree or strongly agree that they have sufficient skills and knowledge for rice farming practises (Figure 4c). Respondents tend to be pessimistic in terms of the future of farming, with more than 70% of respondents stating they disagree or strongly disagree that their children should become farmers, and almost half of the respondents do not want their children to continue working on their farm (Figure 4d).

4.4 | Intention and perception about the irrigated reservoir policy

The results reveal that 64% of respondents intend to convert their farm to irrigated rice-field if they have the opportunity, while 36% do not plan to undertake a conversion (Figure 5a). The survey asked respondents' opinions about the IR policy. The coded answers are presented in the Word Cloud, in which the word size represents the frequency of respondents' opinion (Figure 5b). The local perception of the IR policy does not only refer to the rice-farming opportunities, but also reflects opportunities to improve local water supply more generally and create new job opportunities for the

TABLE 2 Respondent socio-economic characteristics

Respondent characteristics	Respondents ($N = 416$) Mean	SD	Min	Max
Respondent age	47	11	22	80
Rice farmers ($N = 77$)	48	12	24	80
Non rice farmer ($N = 339$)	46	11	22	75
Education years	8.2	3.5	0	16
Rice farmers ($N = 77$)	9.1	3	1	16
Non rice farmer ($N = 339$)	8	4	0	16
HH members (persons)	4	1.1	1	9
Rice farmers ($N = 77$)	4	1.2	2	9
Non rice farmer ($N = 339$)	4	1.1	1	8
Annual household income (million IDR)				
Total income ($N = 416$)	22.8	24.1	−8.9	304
Rice farming	0.7	3.6	−1.4	28.7
Coffee farming	12.6	18.1	−8.9	294.9
Other crops	1.7	6.9	−24.3	61.1
Other income (non-farm)	3.8	2.5	−13.9	552.3
Rice farmers ($N = 77$)	21.9	15	1.4	76.3
Non rice farmers ($N = 339$)	23.1	25.7	−8.9	304

TABLE 3 Farm plot characteristics

Plot characteristics	Respondents ($N = 416$) Mean	SD	Min	Max
Total farm plots ($N = 950$ plots, 416 respondents)				
Total plots per household (n)	2.3	1	1	8
Total plot size per household (ha)	0.80	1	0.1	10
Rice fields (ha)[a]	0.56	0	0	2
Coffee AF (ha)	0.88	1	0	10
Other crops (ha)	0.63	1	0	4.2
Rice farmers farm plots ($N = 88$ plots, 77 respondents)				
Total plots per household (n)	3	1	1	6
Total plot size per household (ha)	2.1	1.3	0.4	8.8
Rice fields (ha)	0.56	0	0	2
Coffee AF (ha)	0.89	0.8	0	5
Other crops (ha)	0.77	0.8	0	2.5
Non rice farmers farm plots ($N = 862$ plots, 339 respondents)				
Total plots per household (n)	2	1	1	8
Total plot size per household (ha)	1.71	1.3	0.1	10
Coffee AF (ha)	0.88	1	0	10
Other crops (ha)	0.60	0.6	0	4.2

[a]The average plot size for rice-farm households ($N = 77$).

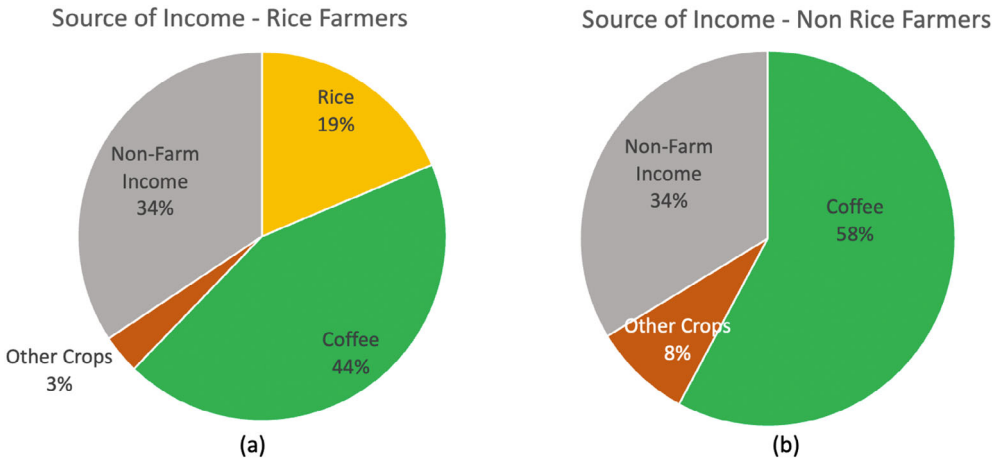

FIGURE 2 Proportion of household income for (a) Rice farm households and (b) non-rice farm households in Pagar Alam

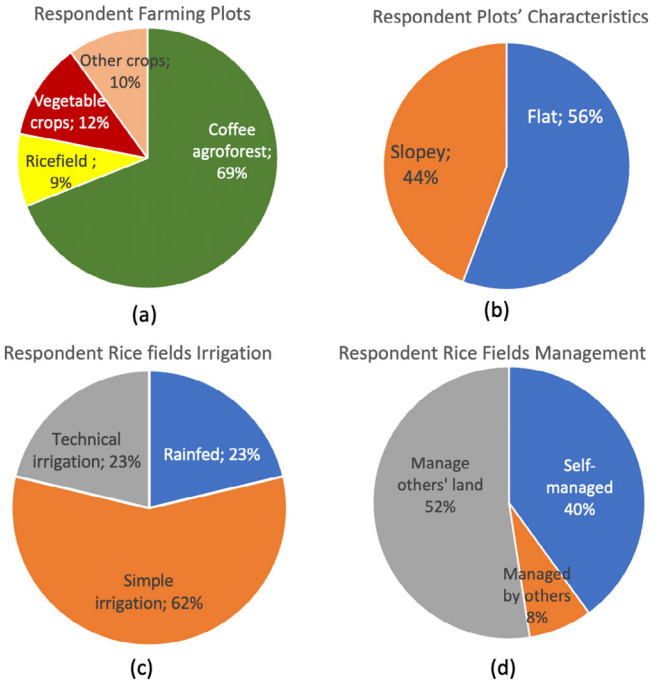

FIGURE 3 (a) Proportion of respondent plots based on farming system (b) respondent plot slope, (c) respondent (rice farmers) rice field irrigation and (d) respondent (rice farmers) rice field management status

upland communities. A few farmers specifically mention opportunities for fisheries and vegetable farming from the presence of reservoir and irrigation networks. Several farmers expressed concerns about the IR, such as unsuitability of the landscape and the negative impacts that irrigation may bring by converting the upland forested landscapes into a massive reservoir.

For each plot, respondents were asked about the crops that they cultivated 5 years before and the crops that they might cultivate in each land plot over the next 3 years. Coffee has been and will continue to be the main crops for the next 3 years, while vegetable and rice crops are expected to increase. Respondents' expectations to manage more rice plots conflict with the experienced land use trend over the previous past 5 years, which saw the number of rice plots decreasing from 112 to 88 plots (Figure 5c).

The understanding of trust levels among community groups and networks is critical to promote collective actions required for irrigation sustainability (Pretty & Ward, 2001). Respondents revealed low levels of trust in residents of neighbouring villages (45.7%) when collaborating on livelihood activities, while they displayed good levels of trust in government, fellow farmer group members, and their village members (Figure 5d).

4.5 | Sustainability of irrigation reservoir in the upland of Pagar Alam

This section discusses the sustainability challenges, threats, and opportunities of IR policy towards the upland landscapes of Pagar Alam, with the use of the socio-cultural, political, environmental, and economic dimensions. The assessment reveals that a new secure water supply for irrigation provides opportunities for farmers to diversify their crops and access new non-farm livelihoods. Nevertheless, the results indicate that the IR policy focusing on food production also generates risks to the local community and environment.

4.5.1 | Economic dimension

Economic sustainability is discussed in relation to the profitability and markets of the existing and proposed farming systems. From the household survey, the total farm plot area and the annual income of farm households are dominated by coffee farming (Table 2). Even for households that practise rice farming, income from rice only contributes 19% of their annual income, while coffee farming provides 44% (Figure 2a). Within the next 3 years the vision of most farmers is to retain and expand coffee agroforestry, with few expecting to shift their farming parcels to rice and vegetable crops (Figure 5c). This result suggests that Pagar Alam farmers are primarily coffee farmers, with some having rice plots for diversification. The presence of irrigation networks will bring various on-farm and non-farm opportunities for further local livelihood diversification. Farmer respondents described several further possibilities in addition to rice farming, such as new employment opportunities, vegetable crops and fisheries (Figure 5b).

IR policy proponents argue that irrigation improves rice production and household welfare from rice farming activities. Yet, a recent agricultural profitability study in Pagar Alam found that irrigated rice farming only provides a 27% Return on Investment (RoI) due to high input and labour costs, compared to a 38% RoI for vegetable crops and a 71% RoI for coffee (Isnurdiansyah et al., 2021). Considering the small land sizes held by households (Table 3) and the high cost of rice farming, ongoing diversification between rice and other cash crops is unlikely to generate sufficient efficiencies for the additional wealth creation that would incentivise households to replace coffee farming as their primary income source.

The state's strong control over rice pricing often forces farmers to sell their harvest below production cost (Octania, 2021). Even when the actual retail price of rice is above the government-regulated prices, rice farmers generally do not benefit, and the income from rice farming alone for smallholder farming households is considered too low to help them out of poverty (Octania, 2021). For upland farmers, rice production may fulfil food security targets, but sustainability will not be achieved if the practise cannot provide sufficient income.

Emerging high value coffee chains are gradually connecting local farmers with niche markets at national and global levels. Pagar Alam coffee farmers are starting to respond to market demand by shifting from traditional to modern practises, focusing increasingly on quality and yield (Mulyoutami et al., 2021). Smallholders cultivate the majority of coffee agroforests in the forest buffer area of Pagar Alam. By simultaneously supporting forest cover and conservation, the production system brings opportunities for links to coffee-certification schemes,

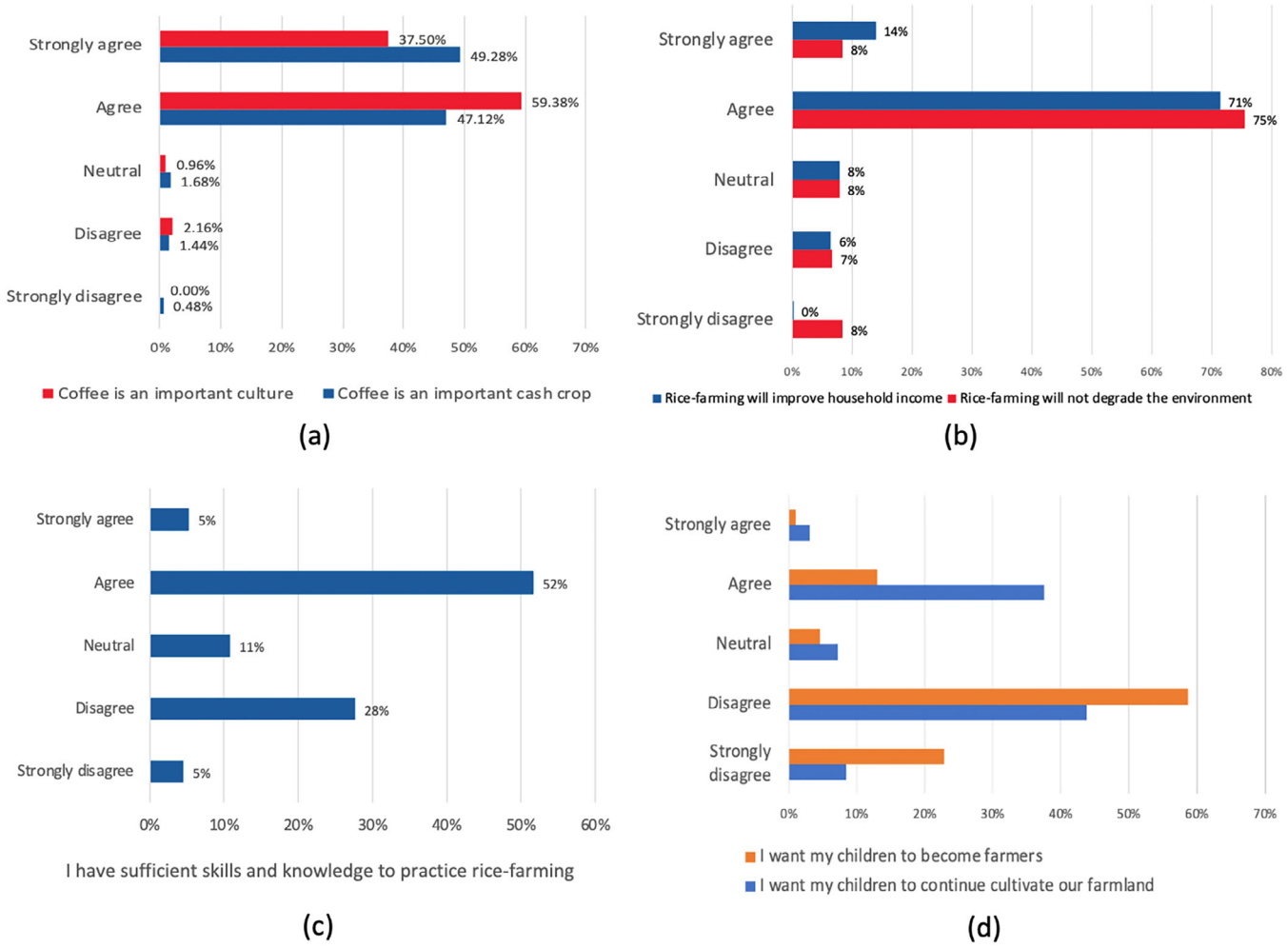

FIGURE 4 Farmers' (a) attitudes towards coffee farming, (b) attitudes towards rice farming, (c) perception of capacity to practise rice farming and (d) attitudes towards the future of farming

as are underway elsewhere in Southern Sumatra, generating significant additional income for farmers (Arifin et al., 2022).

This untapped opportunity for coffee farming in Pagar Alam could be optimised to improve social welfare and achieve economic sustainability from local farming systems. By heavily focusing on rice production opportunities however, the IR policy tends to ignore the comparative advantage of upland agriculture to optimise coffee farming (Arifin et al., 2022). In fact, that opportunity could be threatened by the presence of IR policy that will focus on the conversion of coffee agroforestry areas. Lastly, with a large investment in infrastructure to pursue rice production, there is an important question as to whether such external economic investment will be worthwhile to pursue with regards to local trade-offs in profitability and market opportunities.

4.5.2 | Socio-cultural dimension

As the survey indicates and is well acknowledged in the literature (see Godoy and Bennett (1988), coffee farming is perceived as the cultural identity of farmers in Pagar Alam, framing many activities throughout the year (Figure 5a). Coffee is also the primary source of income for both rice and non-rice farmers (Figure 2). From our respondent sub-set, even the rice farming sub-group ($n = 88$ respondents) have a more significant portion of coffee agroforestry on their land than rice fields.

The presence of IR policy provides opportunities to ensure local food security and achieve cultural goals. Pagar Alam farmers have long been waiting to diversify their farming systems to ensure local food security, as one of the main goals within their culture is to have 'rice to eat and coffee to sell' (Godoy & Bennett, 1988). Irrespective of the opportunity to fulfil food security and livelihood diversification goals, managing irrigated rice fields brings a strong social sustainability challenge for local farmers.

Irrigated rice cultivation is a highly intensive practise that requires sufficient labour, technical and sociocultural capacity. Meanwhile, most respondents perceive coffee farming as their cultural identity (Figure 4a), and 57% perceive having sufficient skills and knowledge to practise rice farming (Figure 4c). Even then, the limited number of self-managed rice fields (Figure 3d) and limited experience in managing technical irrigation (Figure 3c) reflect potential concerns of a lack of

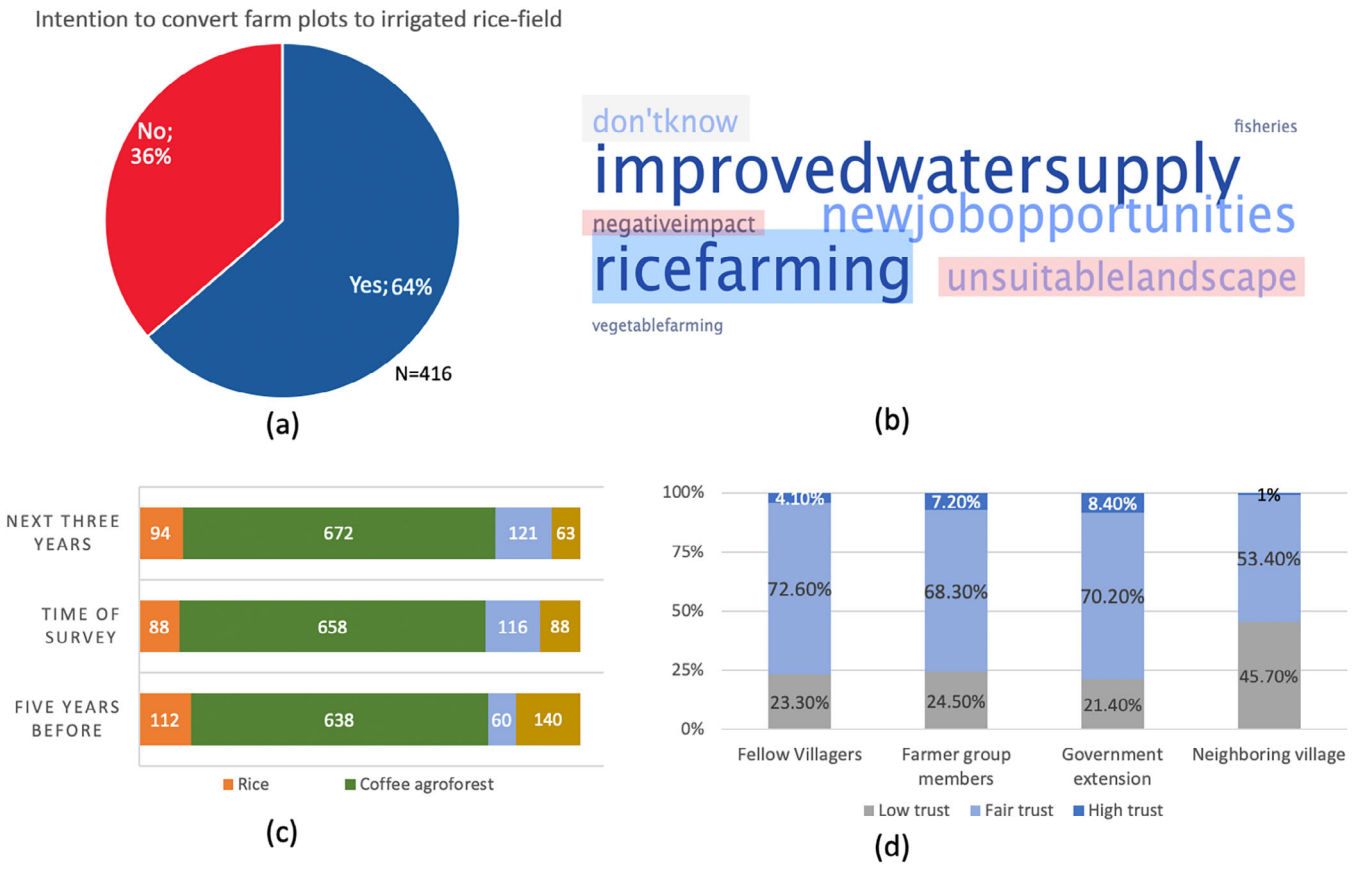

FIGURE 5 (a) Intention to convert the existing plots to irrigated rice-field, (b) perception on the irrigation reservoir policy, (c) respondent farming plot farm trajectory and vision and (d) trust level to collaborate with others in livelihood activities

resources or technical capacities for managing rice farms, which could in turn, affect productivity and sustainability of the IR system.

The upland farmers have strong social capital at the village level, but lower trust towards people from neighbouring villages (Figure 5d). Cultivating irrigated rice fields and managing irrigation requires strong collaboration and cooperation beyond the village level, such as the scheduling of collective planting and harvesting, allocating water supply to farms, and sharing responsibility for regional irrigation maintenance (Alaerts, 2020). Low social capital between villages would hinder effective irrigation and rice-farm management. Policymakers may need to prepare a strategy to improve collaborative actions between villages, to ensure the sustainability of irrigation and rice-farming practises.

Studies demonstrate that a pervasive rice-farming culture significantly correlates with successful irrigation practises in Indonesia, which makes Javanese and Balinese farmers – two regions with a long history of rice-farming – more productive and successful than Sumatran farmers in producing rice (Mariyono, 2014). Rice farming is a complex and highly input-intensive practise, requiring more time, labour, and investment compared to perennial coffee crops. Sumatran farmers have generally preferred perennial crops (Pierce Colfer et al., 1989), so the shift to rice farming will require farmers to significantly change their farming habits from a relatively less intensive perennial to an intensive annual crop.

The rural uplands of Indonesia are facing a transformation where cash crops, labour outmigration and remittances gradually dominate livelihoods (Cramb et al., 2009). The socioeconomic and cultural shift is also occurring in Pagar Alam, where more than 80% of respondents do not want their children to become farmers, and more than 50% do not want their children to continue cultivating their lands (Figure 4d). This social shift away from the farming sector could threaten the social sustainability of irrigated rice farming.

The discussion from the social dimension perspective reveals contrasting aspirations of local farmers. On one hand, there is a long-term goal in the community that having rice fields is necessary to meet food security in parallel with retaining profitable cash crops for financial income. On the other hand, the limited land size per household (Table 3) will be a significant constraint to further diversify farms. These are some of many sociocultural aspects that might hinder the social sustainability of irrigated rice-farming practises in Pagar Alam.

4.5.3 | Political dimension

The IR policy focuses on production increases as the primary means of achieving the national food security target. There is strong support from the government through a range of policies, such as infrastructure

FIGURE 6 The reservoir and irrigation network construction

construction, intensification, capacity building, and empowerment of the local government and local communities (Alaerts, 2020; Ditjen, 2018). Strong support for rice production generates opportunities for sustainable irrigated rice farming at the study site if constraints are taken into account.

While strong political support from the Central Government could help to ensure sustainability, Indonesia's productivist food policy often conflicts with sectoral, regional, and local goals (Vel et al., 2016). Policy aspirations between sectors, within the same sector, and between scales can come into conflict. The updated Nationally Determined Contribution (NDC) states that Indonesia's largest greenhouse gas emitter is deforestation and land-use change, while rice farming and livestock are the third emitters (Government of Indonesia, 2021). Actions to reduce rice farm emissions will be implemented through the utilisation of low-emission crops and improved water management. Applying the national food security policy in the carbon-rich landscape in Pagar Alam could conflict with Indonesia's NDC's aspirations to reduce land clearance and rice farming emissions.

At the provincial level, the Green Growth Masterplan of South Sumatra focuses on improving ecosystem services from the dominant agricultural system, particularly through coffee and rubber agroforestry, to realise green development in the province (South Sumatra Government, 2017). Within the Masterplan, two interventions are specifically targeting Pagar Alam: Intervention 1 'Land-use planning that takes into account the protected area and land suitability' (3440 hectares); and Intervention 6 'Limited expansion for coffee plantation' (8.323 hectares). The national food production target in the upper catchment in Pagar Alam appears to contrast with provincial aspirations to expand coffee plantations, as more area will need to be converted for irrigated rice. Even with an updated land-use zonation plan, the protected forest area in Pagar Alam already limits the expansion of new land uses and these interests have to compete for existing cultivable land.

One of the leading agricultural policies of the local government is the top-grafting of 1 million old coffee trees to improve yields (pagaralamkota.go.id, 2021). Again, this policy targets the same coffee farm landscape as the IR policy. The local agricultural policy focuses on improving the productivity of farmers' coffee crops, and at the local level, it could come into conflict with the national goals of rice production increases.

The discussion of the political dimensions reveals opportunities from central government support for important food production policy in the upland landscape. However, regional and local policies that aim to take advantage of opportunities provided by perennial cash crops contrast with national policy targets.

4.5.4 | Environmental dimension

Due to increasing production costs and decreasing profitability from rice farming, many smallholders farmers in Indonesia are abandoning agriculture or converted their rice fields, with the annual conversion rate of rice fields to other land uses between 2003 and 2013 reaching 150 to 200 thousand hectares per year (Dessy et al., 2017). That trend of decreasing area of rice fields is also apparent in Pagar Alam (Table 1). Previously, the rice fields that have been converted into commercial and residential land-uses were mostly from low lying areas with relatively flat slopes and better accessibility to local economic centres, indicating that Pagar Alam has already lost some of its most valuable rice production to urbanisation.

The survey revealed that IR would bring opportunities to the local community through improved water supply for the local community. However, there are several threats to the upland environment, especially as the reservoir is being constructed in the upper catchment area next to the border of the protected forest. Therefore, the first threat from IR Policy is the degradation of environmental functions, including biodiversity conservation and water and soil regulation. The targeted IR policy area is in the upper catchment with steep slopes and the proposed areas for irrigated rice farming land are also mainly found on sloping lands. Altering the sloping coffee agroforest land to

generate flat irrigated rice fields will require high levels of investment and considerable labour and technical work to make the sub-optimal environment feasible for cultivating irrigated rice.

The reservoir construction alters the river to increase the water supply to the irrigation channels downstream, adding permanent wall structures to prevent soil erosion along the canals (see Figure 6). Such construction requires intensive maintenance to avoid environmental degradation, particularly soil erosion and water degradation from siltation. Without proper management and maintenance, land-use conversion due to IR policy will threaten downstream environmental quality, particularly via soil and water degradation through siltation.

Several subsequent threats come from the depletion of the ecosystem services from coffee agroforestry, particularly biodiversity, soil and climate services. Agriculture intensification is associated with greenhouse gas emissions, land degradation, excessive water use, soil and water pollution, and biodiversity loss (Tilman et al., 2002). Those threats are also prevalent due to the application of IR policy in Pagar Alam.

The 3000-hectare upland area targeted for irrigated rice farming, represents 5% of the total Pagar Alam area, currently dominated by coffee agroforestry. A recent gendered participatory assessment in Pagar Alam revealed that both female and male farmers perceive that the shade trees in coffee agroforest gardens contribute to the maintenance of soil moisture, climate regulation, erosion control and improved soil fertility in their farms (Mulyoutami et al., 2021). Those same lands in the forest buffer area provide habitat and a biodiversity corridor for wildlife, including endemic species such as the Sumatran Tiger.

The coffee agroforest landscape also provides carbon sequestration and climate regulation services, which are essential to combat climate change. The forest and coffee agroforest landscape of Pagar Alam is estimated to store about 17.2 Million Tonnes Carbon, mainly in the soil (Global Forest Watch, 2021). The massive land-use conversion from agroforest into intensive monoculture rice farming will release considerable carbon dioxide (Erdogan, 2022), while intensive rice farming practises generate methane, and are known to be one of the major carbon emitters from Indonesia's agricultural sector (Rondhi et al., 2019).

There is a potential trade-off between the potential benefits of improving the local water supply and various environmental threats at farm and landscape levels. The discussion suggests that there are more threats to local ecological sustainability than opportunities from the IR policy. Respondents indicated the unsuitability of the landscape for the IR and rice farming (Figure 5b). Nevertheless, respondents predominantly believe that rice farming will not degrade the environment (Figure 4b). Such a belief could be realised with support from solid precautionary actions on farm and landscape management involving farmers and the local government. However, to ensure IR policy will provide positive environmental outcomes, threats from land-use conversion towards coffee agroforest ecosystem services, particularly climate and biodiversity, will need to be carefully considered and continually evaluated.

5 | DISCUSSION AND POLICY-RESEARCH IMPLICATIONS

Agriculture is a complex system, and policy that aims to promote its sustainability should carefully consider the characteristics of people and places to deliver sustainable outcomes. Our results demonstrate how socio-cultural, political, environmental, and economic development outcomes are intertwined within upland agricultural activities. In the upland site, we identified that development pathways were already moving towards a sustainable direction, including *farmers' culture and identities*, *local–global coffee market integration* and *climate mitigation*, and are reflected in the *local and regional development agenda*. While IR policy would contribute to national food production targets, existing development pathways may be overlooked, and new risks could threaten upland communities and landscapes if the policy were not being implemented carefully. There is also a potential gap between national rice sufficiency goals and the local reality, which sees most farmers aspiring only to grow sufficient rice for food to meet household needs. As farmers are both the beneficiaries and agents of sustainable development, national agricultural policies need to carefully reflect local needs of farmers and promote ways to maintain and improve sustainable outcomes from the existing practises for upland regions (Terlau et al., 2018).

Contemporary agricultural development strategies emphasise the multi-functional roles of agriculture in eliminating hunger and poverty, improving nutritional outcomes, addressing inequality, contributing to environmental conservation, and supporting various non-production benefits for present and future generations (FAO, 2022; Stringer, 2016). Like in other forested agricultural landscapes in Southeast Asia, food security in many parts of rural Indonesia is mainly met through income security from perennial crops, which also provide a range of ecological and non-production functions (van Noordwijk et al., 2014). At global and national levels, countries can strengthen cross-sectoral and multi-scalar development coordination to improve the contribution of agricultural systems to achieve sustainable development (Neely et al., 2017). In the upland of Pagar Alam, the potential misalignment of the IR policy agenda with other sectoral and regional agendas could inhibit optimum outcomes for food production and environmental conservation.

Realising sustainable reservoir systems for agriculture and other development purposes is likely to be critical for achieving the SDGs 2030 targets (Guo et al., 2021). Global lessons indicate that IR policy developed without sufficiently considering its impacts on local communities and ecosystems have the potential to generate substantial adverse impacts. One important example is the major diversions for agricultural irrigation in the Murray-Darling Basin of Australia, where there has been a history of degraded ecosystems and water supply problems, followed by social conflict (Ballard, 2020; Pollino et al., 2021). Another example of an irrigation network that appears to lack long-term sustainability is the Chotiari Reservoir in Pakistan, which again has been associated with degraded wetland ecosystems and environmental and economic disasters (Magsi & Torre, 2014; Siyal et al., 2019). Reservoir development and associated agricultural

policies could avoid such adverse development trajectories by closely examining how policy will impact on multiple dimensions of sustainability in the long-term.

With about 720 to 811 million people globally estimated to face hunger in 2020, an addition of 118 to 161 million more people from a 2019 baseline, much more progress in providing food and nutritional improvements is needed to reduce risks to national social well-being and security, especially in association with the COVID-19 pandemic, resource constraints, climate change, and economic destabilisation (FAO et al., 2021). The agricultural sector will need to continue to play a significant role in achieving the SDGs by 2030 while recovering from contemporary global modernity crises (FAO et al., 2021; van Noordwijk et al., 2018). Yet, sustainable agriculture is likely to be increasingly difficult to attain via policy and research approaches that overly focus on single, short-term goals.

To generate positive broad, sustained impacts from agricultural policy, Indonesia and the global agri-food research and policy communities should consider moving beyond the focus on productivity targets and work explicitly to reconcile national food production goals with other equally important national, regional and local development agendas. Such reconciliation could be facilitated through sufficient understanding of the local people, places and ecosystems (Amaruzaman et al., 2022) and improving coordination between governance scales and sectors (Neely et al., 2017).

The acceleration of progress towards the SDG 2030 requires agricultural policy to be coherent with other sectoral policies targeting diverse agro-ecosystems. Agricultural sustainability research will play a significant role in informing policy design, enhancing policy coherence and promoting the integration of complex goals in the agricultural sector (FAO, 2018; Streimikis & Baležentis, 2020; Stringer, 2001). As part of this role, assessment frameworks should work to provide measurable and comparable results between places and yet be sufficiently flexible to represent the site-specific characteristics of local agroecosystems. To achieve the latter objective, the research and policy community could take more consideration of the specific traits of local places as well as the values, aspirations, and motivations of people that will affect and be impacted by the agricultural policy outcomes.

Research for agricultural policy framing needs to move beyond a reductionist approach that relies on a limited set of indicators or overly focuses on the specific sustainability domains and scales (Gasparatos et al., 2008). The knowledge generation process to inform policy framing would require a careful consideration of different perspectives and goals from various stakeholders (Armitage, 2004; Moskwa et al., 2018). By conceptualising opportunities and risks, the bottom-up integrated assessment approach applied here could be beneficial to improve the sustainability of agricultural policy and programs in place-specific contexts (Binder et al., 2010; Schader et al., 2014). Managing transitions to sustainability requires the comprehensive understanding of policy impacts across multiple development domains at different scales (Cantone et al., 2021). As demonstrated in the analysis, the integrated and descriptive approach allows for an in-depth reflection on the potential outcomes from IR policy across multiple sustainability dimensions and scales.

6 | CONCLUSION

This paper assesses the sustainability of IR policy targeting the upland area of Pagar Alam, Indonesia. The policy focuses on improving rice production for national food security by expanding irrigated rice fields through the establishment of a reservoir and irrigation infrastructure. Through a bottom-up approach that integrates multi-dimensional perspectives, we revealed diverse opportunities and threats from the policy that may affect the sustainability. Our assessment indicates that the IR policy, which overly focuses on a productivity goal, has the potential to generate policy outcomes that vastly differ from and potentially diminish the existing sustainability pathways of the upland area.

Agricultural policy research and action should apply a comprehensive approach that addresses multiple sustainability dimensions, to optimise policy outcomes in association with various development agendas. Our study enriches the literature by demonstrating the application of an alternative, bottom-up integrated and descriptive approach to assess agricultural sustainability. The integrated and descriptive approach allows us to have a degree of comprehensiveness in discussing the trade-offs across the dimensions of sustainability. This approach can simultaneously address diverse development agendas, and the results can be used further to communicate, select, and synergise preferred pathways for people and landscape. Lastly, this study adds to the literature on agri-environmental sustainability in the upland context of Indonesia and debates on the sustainability of IRs for agricultural development.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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REFERENCES

Alaerts, G. J. (2020). Adaptive policy implementation: Process and impact of Indonesia's national irrigation reform 1999–2018. *World Development*, *129*, 104880.

Alaoui, A., Barão, L., Ferreira, C. S. S., & Hessel, R. (2022). An overview of sustainability assessment frameworks in agriculture. *Land*, *11*, 537.

Amaruzaman, S., Bardsley, D. K., & Stringer, R. (2022). Reflexive policies and the complex socio-ecological systems of the upland landscapes in Indonesia. *Agriculture and Human Values*, *39*, 683–700.

Amaruzaman, S., Isnurdiansyah, I., Nugraha, M., Lusiana, B., & Leimona, B. (2021). *Profile of the production landscape of Pagar Alam: Towards sustainable upland agriculture*. World Agroforestry (ICRAF) Indonesia Country Program.

Arifin, B., Reed, M., Rosanti, N., Ismono, H., & Budiyuwono, S. (2022). Partnership for sustainable coffee certification: Linking up smallholder farmers to global coffee market. *Sustainability Science and Resources*, *2*, 24–44.

Armitage, D. (2004). Nature–society dynamics, policy narratives, and ecosystem management: Integrating perspectives on upland change and complexity in Central Sulawesi, Indonesia. *Ecosystems*, *7*, 717–728.

Ballard, C. (2020). Management of Murray–Darling Basin, Australia. *Irrigation and Drainage*, *69*, 504–516.

Bardsley, D. K. (2015). Limits to adaptation or a second modernity? Responses to climate change risk in the context of failing socio-ecosystems. *Environment, Development and Sustainability*, *17*, 41–55.

Bardsley, D. K., & Knierim, A. (2020). Hegel, Beck and the reconceptualization of ecological risk: The example of Australian agriculture. *Journal of Rural Studies*, *80*, 503–512.

Belsky, J. M. (1994). Soil conservation and poverty: Lessons from upland Indonesia. *Society & Natural Resources*, *7*, 429–443.

Binder, C. R., Feola, G., & Steinberger, J. K. (2010). Considering the normative, systemic and procedural dimensions in indicator-based sustainability assessments in agriculture. *Environmental Impact Assessment Review*, *30*, 71–81.

BPS Pagar Alam. (2017). Pagar Alam City in figures 2020. Biro Pusat Statistik Kota Pagar Alam, Pagar Alam, Indonesia.

BPS Sumatera Selatan. (2021). Sumatra Selatan Province in figures 2020. Biro Pusat Statistik Provinsi Sumatera Selatan, Palembang, Indonesia.

Cantone, B., Antonarakis, A. S., & Antoniades, A. (2021). The great stagnation and environmental sustainability: A multidimensional perspective. *Sustainable Development*, *29*, 485–503.

Clough, Y., Krishna, V. V., Corre, M. D., Darras, K., Denmead, L. H., Meijide, A., Moser, S., Musshoff, O., Steinebach, S., Veldkamp, E., Allen, K., Barnes, A. D., Breidenbach, N., Brose, U., Buchori, D., Daniel, R., Finkeldey, R., Harahap, I., Hertel, D., … Scheu, S. (2016). Land-use choices follow profitability at the expense of ecological functions in Indonesian smallholder landscapes. *Nature Communications*, *7*, 13137.

Cramb, R. A., Colfer, C. J. P., Dressler, W., Laungaramsri, P., Le, Q. T., Mulyoutami, E., Peluso, N. L., & Wadley, R. L. (2009). Swidden transformations and rural livelihoods in Southeast Asia. *Human Ecology*, *37*, 323–346.

Dessy, A., Elisa, W., Idham, A., & Mustofa, H. M. (2017). Technological innovation and business diversification: Sustainability livelihoods improvement scenario of rice farmer household in sub-optimal land. *Russian Journal of Agricultural and Socio-Economic Sciences*, *69*, 77–88.

Di Iacovo, F. (2014). Agriculture and social sustainability. In B. De Gennaro & G. Nardone (Eds.), *Sustainability of the Agri-food System: Strategies and Performances. Proceedings of the 50th SIDEA Conference. Lecce, Chiostro dei Domenicani, 26-28 September 2013* (pp. 25–44). Universitas Studiorum.

Ditjen, S. D. A. P. U. (2018). Program Pengembangan dan Pengelolaan Sistem Irigasi di Indonesia Kementerian PUPR, Jakarta: Indonesia.

El Bilali, H., Strassner, C., & Ben Hassen, T. (2021). Sustainable agri-food systems: Environment, economy, society, and policy. *Sustainability*, *13*, 6260.

Erdogan, S. (2022). Investigating the effects of food production on sustainable development: The case of the upper middle-income countries. *Sustainable Development*, *30*, 606–619.

FAO, IFAD, UNICEF, WFP, WHO. (2021). The state of food security and nutrition in the world 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all., the state of food security and nutrition in the world (SOFI), Rome, Italy, p. #240.

FAO. (2014a). SAFA (sustainability assessment of food and agriculture systems) guidelines - version 3.0. Rome, Italy.

FAO. (2014b). Sustainability assessment of food and agriculture systems (SAFA). FAO.

FAO. (2018). Sustainable food systems: Concept and framework. Technical Brief.

FAO. (2022). Sustainable agriculture.

Gasparatos, A., El-Haram, M., & Horner, M. (2008). A critical review of reductionist approaches for assessing the progress towards sustainability. *Environmental Impact Assessment Review*, *28*, 286–311.

Global Forest Watch. (2021). Carbon stock in Pagar Alam.

Godoy, R., & Bennett, C. (1988). Diversification among coffee smallholders in the highlands of South Sumatra, Indonesia. *Human Ecology*, *16*, 397–420.

Government of Indonesia. (2021). Updated nationally determined contribution - Republic of Indonesia. In: Forestry, M.o.E.a. (Ed.).

Guo, Z., Boeing, W. J., Borgomeo, E., Xu, Y., & Weng, Y. (2021). Linking reservoir ecosystems research to the sustainable development goals. *Science of the Total Environment*, *781*, 146769.

Hadi, D. P., & van Noordwijk, M. (2005). Agro-ecosystems, their population densities and land cover in Indonesia in the context of upland-lowland relationships. RUPES working paper. ICRAF-Southeast Asia, Bogor.

Isnurdiansyah, I., Amaruzaman, S., Lusiana, B., & Leimona, B. (2021). *Production-landscape characteristics and vision through the lens of upland smallholders in Pagar Alam, Indonesia*. World Agroforestry (ICRAF) Indonesia Country Program.

Janker, J., Mann, S., & Rist, S. (2019). Social sustainability in agriculture – A system-based framework. *Journal of Rural Studies*, *65*, 32–42.

Lang, T., & Barling, D. (2012). Food security and food sustainability: Reformulating the debate. *The Geographical Journal*, *178*, 313–326.

Leimona, B., Amaruzaman, S., Arifin, B., Yasmin, F., Hasan, F., Agusta, H., Sprang, P., Jaffee, S., & Frias, J. (2015). Indonesia's 'green agriculture' strategies and policies: Closing the gap between aspirations and application. Occasional paper 23. Nairobi: World Agroforestry Centre.

Li, T. M. (2002). Engaging simplifications: Community-based resource management, market processes and state agendas in upland Southeast Asia. *World Development*, *30*, 265–283.

Magsi, H., & Torre, A. (2014). Proximity analysis of inefficient practices and socio-spatial negligence: Evidence, evaluations and recommendations drawn from the construction of Chotiari reservoir in Pakistan. *Land Use Policy*, *36*, 567–576.

Mariyono, J. (2014). Rice production in Indonesia: Policy and performance. *Asia Pacific Journal of Public Administration*, *36*, 123–134.

Moskwa, E., Bardsley, D. K., Robinson, G. M., & Weber, D. (2018). Generating narratives on bushfire risk and biodiversity values to inform environmental policy. *Environmental Science & Policy*, *89*, 30–40.

Mulyoutami, E., Martini, E., & Roshetko, J. (2021). *An overview of the potential impacts of interventions on diverse coffee agroforestry system to gender dynamics in Pagar Alam District, South Sumatera*. World Agroforestry (ICRAF) Indonesia Country Program.

Nasrullah, & Ovitasari, M. (2022). Regulatory and policy responses toward SDGs in achieving sustainable agriculture productivity in Indonesia. In *IOP conference series: Earth and environmental science* (p. 12027). IOP Publishing.

Neely, C., Bourne, M., Chesterman, S., Kouplevatskaya-Buttoud, I., Bojic, D., & Vallée, D. (2017). *Implementing agenda 2030 in food and agriculture: Accelerating policy impact through cross-sectoral coordination at the country level*. FAO.

Octania, G. (2021). The government's role in the Indonesian rice supply chain. Policy Paper. Center for Indonesian Policy Studies (CIPS), Jakarta.

pagaralamkota.go.id. (2021). Gerakan sejuta sambung pucuk tanaman kopi terima penghargaan MURI. Pagar Alam Government.

Panuju, D. R., Mizuno, K., & Trisasongko, B. H. (2013). The dynamics of rice production in Indonesia 1961–2009. *Journal of the Saudi Society of Agricultural Sciences*, *12*, 27–37.

Peluso, N. L. (1993). 'Traditions' of forest control in Java: Implications for social forestry and sustainability. *Global Ecology and Biogeography Letters*, *3*, 138–157.

Pierce Colfer, C. J., Newton, H., & Barbara, J. (1989). Ethnicity: An important consideration in Indonesian agriculture. *Agriculture and Human Values*, *6*, 52–67.

Pollino, C. A., Hart, B. T., Nolan, M., Byron, N., & Marsh, R. (2021). Rural and regional communities of the Murray–Darling basin. In B. T. Hart, N. R. Bond, N. Byron, C. A. Pollino, & M. J. Stewardson (Eds.), *Murray-Darling Basin* (pp. 21–46). Elsevier.

Pretty, J., & Ward, H. (2001). Social capital and the environment. *World Development*, *29*, 209–227.

Quincieu, E. (2015). Summary of Indonesia's agriculture, natural resources, and environment sector assessment. ADB Papers on Indonesia Asian Development Bank, Manila.

Reardon, T., Stringer, R., Timmer, C. P., Minot, N., & Daryanto, A. (2015). Transformation of the Indonesian agrifood system and the future beyond rice: A special issue. *Bulletin of Indonesian Economic Studies*, *51*, 369–373.

Rondhi, M., Fatikhul Khasan, A., Mori, Y., & Kondo, T. (2019). Assessing the role of the perceived impact of climate change on national adaptation policy: The case of rice farming in Indonesia. *Land*, *8*, 81.

Schaafsma, M., Dreoni, I., Ayompe, L. M., Egoh, B., Ekayana, D. P., Favareto, A., Mumbunan, S., Nakagawa, L., Ngouhouo-poufoun, J., Sassen, M., Uehara, T. K., & Matthews, Z. (2022). A framework to understand the social impacts of agricultural trade. *Sustainable Development*. https://doi.org/10.1002/sd.2379

Schader, C., Grenz, J., Meier, M. S., & Stolze, M. (2014). Scope and precision of sustainability assessment approaches to food systems. *Ecology and Society*, *19*.

Singh, B., Keitsch, M. M., & Shrestha, M. (2019). Scaling up sustainability: Concepts and practices of the ecovillage approach. *Sustainable Development*, *27*, 237–244.

Siyal, A. A., Bhatti, A. M., Babar, M. M., Ansari, K., Saher, R., & Ahmed, S. (2019). Environmental impact of conversion of natural wetland into reservoir: A case study of Chotiari reservoir in Pakistan. In *World environmental and water resources congress 2019: Watershed management, irrigation and drainage, and water resources planning and management* (pp. 15–27). American Society of Civil Engineers.

Song, B., Robinson, G. M., & Bardsley, D. K. (2020). Measuring multifunctional agricultural landscapes. *Land*, *9*, 260.

Sonnino, R., Faus, A. M., & Maggio, A. (2014). Sustainable food security: An emerging research and policy agenda. *The International Journal of Sociology of Agriculture and Food*, *21*, 173–188.

South Sumatra Government. (2017). *Towards sustainable development in South Sumatra: Masterplan for renewable land-based green growth 2017–2030*. Government of South Sumatra.

Streimikis, J., & Baležentis, T. (2020). Agricultural sustainability assessment framework integrating sustainable development goals and interlinked priorities of environmental, climate and agriculture policies. *Sustainable Development*, *28*, 1702–1712.

Stringer, R. (2001). How important are the non-traditional economic roles of agriculture in development? *CIES Discussion Paper No. 0118*. Centre for International Economic Studies.

Stringer, R. (2016). Food security global overview. In M. Caraher & J. Coveney (Eds.), *Food Poverty and Insecurity: International Food Inequalities*. Springer.

Talukder, B., & Blay-Palmer, A. (2017). Comparison of methods to assess agricultural sustainability. In E. Lichtfouse (Ed.), *Sustainable Agriculture Reviews* (Vol. 45, pp. 149–168). Springer.

Talukder, B., Hipel, K. W., & van Loon, G. W. (2018). Using multi-criteria decision analysis for assessing sustainability of agricultural systems. *Sustainable Development*, *26*, 781–799.

Tello, E., & González de Molina, M. (2017). Methodological challenges and general criteria for assessing and designing local sustainable agri-food systems: A socio-ecological approach at landscape level. In *Socio-metabolic perspectives on the sustainability of local food systems* (pp. 27–67). Springer.

Terlau, W., Hirsch, D., & Blanke, M. (2018). Smallholder farmers as a Isnurdiansyah backbone for the implementation of the sustainable development goals. *Sustainable Development*, *27*, 523–529.

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature*, *418*, 671–677.

van Noordwijk, M., Bizard, V., Wangpakapattanawong, P., Tata, H. L., Villamor, G. B., & Leimona, B. (2014). Tree cover transitions and food security in Southeast Asia. *Global Food Security*, *3*, 200–208.

van Noordwijk, M., Duguma, L. A., Dewi, S., Leimona, B., Catacutan, D. C., Lusiana, B., Öborn, I., Hairiah, K., & Minang, P. A. (2018). SDG synergy between agriculture and forestry in the food, energy, water and income nexus: Reinventing agroforestry? *Current Opinion in Environmental Sustainability*, *34*, 33–42.

Vel, J. A. C., McCarthy, J. F., & Zen, Z. (2016). The conflicted nature of food security policy: Balancing rice, sugar and palm oil in Indonesia. *Anthropological Forum*, *26*, 233–247.

World Bank (2021). *Indonesia Vision 2045: Toward Water Security*. World Bank, Washington, DC.

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