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Livelihood Strategies, Resilience and Coping in the Highlands of Central Java: What Difference does Agroforestry make?

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“But intending to understand ten things, you actually do not understand even one.
If you know a hundred flowers you do not “know” a single one.”

Masanobu Fukuoka, The One-Straw Revolution

Declaration of Academic Integrity

I declare in lieu of an oath that I have written this paper autonomous and independently, that I have not used any auxiliary materials other than those indicated, and that I have cited all formulations and concepts taken from unprinted sources, printed literature, or the internet in their wording or essential content in accordance with the guidelines for scientific papers, and that I have marked them with footnotes or indicated them with precise references. Further, this written work has not yet been submitted to any authority.

24th Oct. 2021, Vienna
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Abstract

Smallholders in South-East Asia are confronted with market forces and climate change impacts but continue to persist by diversifying their livelihoods. In the uplands of the Merawu watershed in Banjarnegara, Central Java, livelihood strategies correspond to market demands and depend on sub-livelihood sized farms. High erosion loads have been measured in the watershed and anecdotal observations suggests that two distinct farming styles exist, with different implications for the environment and livelihood resilience. Agroforestry has been suggested as a key solution to foster livelihood stability while preserving the natural resource base. However, a national potato boom is suspected to have taken hold of smallholders in the area. The present research tackles this nexus by investigating livelihood strategies and diversification, household resilience and coping strategies. The sustainable livelihood framework as a conceptual approach and an agroecological indicator framework for livelihood resilience is adopted. The analysis of key household variables with the exhaustive CHAID classification tree model revealed the existence of two major livelihood strategies. While households following the agroforestry strategy applied diversified crop-livestock systems with interspersed implementation of value and fruit trees, households following the intensive cropping boom in the conventional strategy had a significantly lower level of diversification but used high levels of farm inputs. No significant difference in per capita incomes between the strategies existed. However, the overall livelihood resilience of agroforestry households was significantly higher, as well as in the resilience dimensions of buffer capacity, capacity for learning and adaptation, and capacity for self-organisation. Congruently, the likelihood for applying a positive coping strategy was higher for an increase in each capacity and lower for households following the conventional strategy, albeit results depend on interpretation of credit use. Overall, the results carry implications for the conceptual use of the sustainable livelihood framework and its operationalisation in an indicator system. Further research into the connection between livelihood strategies, resilience and coping is endorsed.

Keywords: *Central Java, livelihood diversification, livelihood resilience, agroforestry, smallholder*

Zusammenfassung

Kleinbauern in Südostasien sind mit den Kräften des Marktes und den Auswirkungen des Klimawandels konfrontiert. Diversifizierung ihrer Lebensgrundlagen und landwirtschaftlichen Betriebe bildet dabei eine wichtige Strategie für ihre Existenzsicherung. Im Hochland des Merawu-Wassereinzugsgebiets in Banjarnegara, Zentral-Java, entsprechen die Existenzstrategien der Marktnachfrage während Haushalte auf Flächen wirtschaften die als zu klein gelten, um ihre Lebensgrundlagen sichern zu können. Im Wassereinzugsgebiet wurden hohe Erosionsbelastungen gemessen und anekdotische Beobachtungen deuten darauf hin, dass es zwei verschiedene landwirtschaftliche Strategien mit unterschiedlichen Auswirkungen auf die Umwelt und die Resilienz gegenüber Klimawandel und Markt-Shocks gibt. Agroforstwirtschaft wurde als eine wichtige Lösung vorgeschlagen, um die Stabilität des Lebensunterhalts zu fördern und gleichzeitig die natürlichen Ressourcen zu erhalten. Es wird jedoch vermutet, dass ein nationaler Kartoffelboom die Kleinbauern in der Region erfasst hat. Die vorliegende Studie befasst sich mit diesem Nexus, indem sie die Strategien zur Sicherung der Lebensgrundlagen und der Diversifizierung, die Resilienz der Haushalte und Bewältigungsstrategien untersucht. Das Sustainable Livelihood Framework als konzeptioneller Ansatz und ein agrarökologischer Indikatorrahmen für die Resilienz von Haushalten werden verwendet. Die Analyse der socio-ökonomischen Charakteristika der Haushalte mit dem umfassenden CHAID-Klassifikationsbaummodell zeigte die Existenz von zwei dominanten Strategien für den Lebensunterhalt. Während die Haushalte, die der Agroforststrategie folgten, diversifizierte Ackerbau-Viehhaltungssysteme mit eingestreuter Implementierung von Wert- und Obstbäumen anwandten, hatten die Haushalte, die dem Kartoffelanbau in der konventionellen Strategie folgten, einen signifikant niedrigeren Diversifizierungsgrad, aber einen mehrfach höheren Input. Es gab keinen signifikanten Unterschied im Pro-Kopf-Einkommen zwischen den Strategien. Allerdings war die allgemeine Resilienz der Agroforsthaushalte signifikant höher, ebenso wie in den Resilienz-Dimensionen Pufferkapazität, Lern- und Anpassungsfähigkeit und Fähigkeit zur Selbstorganisation. Übereinstimmend war die Wahrscheinlichkeit für die Anwendung einer positiven Bewältigungsstrategie höher für eine Erhöhung jeder Kapazität und niedriger für Haushalte, die die konventionelle Strategie verfolgten, obwohl die Ergebnisse von der Interpretation der Kreditnutzung abhängen. Insgesamt haben die Ergebnisse Implikationen für die konzeptionelle Anwendung des Sustainable Livelihood Frameworks und seine Operationalisierung in dem Indikatorensystem. Weitere Forschung zum Zusammenhang zwischen Lebensgrundlangen-Strategien, Resilienz und Bewältigung wird befürwortet.

Keywords: *Zentral-Java, Einkommens-Diversifizierung, Resilienz, Agroforstwirtschaft, Kleinbauern*

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Abbreviations

BOKU	Universität für Bodenkultur
DRR	Disaster Risk Reduction
SEA	South-East Asia
SLA	Sustainable Livelihood Approach
SLF	Sustainable Livelihood Framework
UGM	Universitas Gadjah Mada

1. Introduction

1.1. The persistence of smallholder agriculture in SEA and its vulnerability to climate change

Globally, estimations count about 570 million farms of which the majority of 84% are smallholder holdings operating on farms smaller than 2 hectares (Fritz et al., 2015; Lowder et al., 2016). Many characteristics are ascribed to them academically and by international organisations, interpretations of data being subject to research tradition or political views: they supposedly constitute the majority of the worlds' poorest and are caught in poverty traps, but their livelihood strategy can free them from poverty while simultaneously feeding the world (Banerjee & Duflo, 2007; IFAD, n.d.; Rapsomanikis, 2015; Samberg et al., 2016; Wegner & Zwart, 2011; Wiggins, 2009). However, output in smallholder farms that often operate on sub-livelihood sized farms is either related to high input intensity of inexpensive labour capacity, attributable to crop-booms, or complemented by livelihood diversification (Gollin, 2019b; Rigg et al., 2016; Rigg & Salamanca, 2017).

Rigg and Vandergeest (2012) found in their revisitation of rural places that the continuation of smallholder agriculture with a sub-livelihood farm size is largely possible due to livelihood diversification, engaging in the rural off-farm economy, or relying on remittances. The capitalist transition and the effects of the Green Revolution in SEA has against expectations led to the *"the stubborn persistence of the smallholder"* which originates from the *"creative combination of livelihood activities"* (Rigg & Salamanca, 2017, p. 45). Instead of following the neoliberal model of wealth accumulation by dispossession (increase of farm size and intensification, or diversification that leads to farm exit), smallholders reverted to accumulation by continuation of connection to means of production, or livelihood diversification (ibid.). Despite the introduction of new agricultural technologies, the push of market forces (economies of scale and international competition) and idealistic policy aims of international organisations (intensification for wealth accumulation) that both push the farm-size transition, smallholders continue to persist in SEA even after the introduction of new farming technology by the Green Revolution (Rigg et al., 2016). Overall, the Green Revolution in SEA is associated with an increase in off-farm work, partially owed to the development of value chains, and rural incomes, and subsequently, the reduction of rural poverty (Henley, 2012). These developments are seen problematic by some international organisations and scholars, as the decrease in farm size supposedly compromises the survival of the household, and leads to the loss of comparative advantage in Agriculture of the region (Otsuka, 2013; as cited in Rigg & Salamanca, 2017). In this context, an intrinsic pattern of pluractivity and occupational multiplicity emerged in rural livelihoods which has diverse temporal (seasonal dependency), social (gender and generational) and spatial (remittances) characteristics (ibid.). These developments also suggest that focusing on eradicating poverty by directly investing in agriculture and smallholders is insufficient, given the dependency on off-farm work or a generally more diversified livelihood (Dercon, 2013; Rigg & Salamanca, 2017). Rigg et al., (2016), describe these dependencies and concomitants as *'produced precarities'* as the smallholder is more subject to market forces, which the Disaster Risk Reduction (DRR) literature terms socially constructed vulnerabilities or manufactured risks; i.e. the increase in vulnerability due to a set of social and economic behaviours, asset levels, believes or conditions (Giddens, 1999; Tierney, 2014; Benjamin Wisner, 2016).

In parallel to these trends in the socio-economic fabric of smallholder agriculture, climate change impacts are projected to be more severe in the global south and may offset progress towards the eradication of poverty (Mearns & Norton, 2009; Rentschler, 2013; Ribot, 2013; Tanner & Allouche, 2011). South-East Asia is prone to climate change by the increase in extreme weather events such heavy precipitation and fierce winds from the Monsoon rains, but also from slow-onset phenomena like the increase of average temperature, or sea level rise and saltwater intrusion (Masson-Delmotte et al., 2018). Indonesia is particularly subject to precipitation variability induced by the El Niño Southern Oscillation (ENSO). The phenomenon and its reoccurring El Niño and La Niña events frequently cause drought or extreme precipitation, and thus affect food production, farm income and livelihood resilience (Keil et al., 2007; Measey, 2010; Naylor et al., 2007; Oktaviani et al., 2011; Syaukat, 2021; Utami et al., 2018). Further climate change is likely to exacerbate climate variability and increase extreme weather events adversely affecting smallholders in rural Central Java, Indonesia, the focus area of this study (Djalante, 2018; Djalante et al., 2017; Masson-Delmotte et al., 2018).

To address this conundrum of small-scale diversified farm systems that are subject to climate impacts and market or political forces, international development research and actors have in the last decades adopted the Sustainable Livelihood Framework (SLF) which offers an eclectic view on the complex circumstances smallholders face globally (De Haan, 2012a; DFID, 1999; Scoones, 1998). Lately, this action and intervention-oriented approach was complemented by a social-ecological systems perspective on agriculture that enables to synergistically address at cross-scale levels the goals of food security, emancipation of peasants, and ecological sustainability under climate change impacts (Ifejika Speranza et al., 2014; Quandt, 2018; Tanner et al., 2015). Livelihood resilience to climate change has emerged as a key concept in tackling vulnerability of rural livelihoods and is on a local level situated amidst this coherent set of goals (Cote & Nightingale, 2012), and has become a prominent concept in global research and action on international development (Tanner et al., 2015). The highly salient *'boundary concept'* lies at the juncture of social-ecological systems, international development and climate change adaptation and is increasingly used to highlight the capacity of livelihoods to respond to climate change impacts (Bahadur et al., 2013; Brand & Jax, 2007; Cannon & Müller-Mahn, 2010; FAO, 2018). Livelihood resilience is a product of the livelihood capitals, i.e., the asset base and access to services, that in turn form livelihood strategies which are influenced by socio-economic, political structures and environmental conditions (compare Section 2.1). Thus, livelihood strategies are an essential component of livelihood resilience formation and although a growing body of literature addresses this connection a research gap of livelihood diversification and resilience in rural Java Indonesia persists (see Section 1.3). Intensification and diversification of income sources and asset base, often with integration of agroecological principles that are crucial to sustain smallholder resilience in the humid tropics, form two major strategies observable in smallholder systems.

1.2. Livelihood strategies and implications for vulnerability and resilience

1.2.1. Agricultural intensification

In the humid tropics agriculture was historically based on periodical shifting cultivation[1], which allows nature to rejuvenate, without the depletion of soils and loss of wildlife (Leakey, 2014; Ziegler et al., 2009). During the Green Revolution, large-scale deforestation and a shift towards intensive monoculture occurred that had a detrimental impact on landscape and wildlife ecology but also on livelihoods that depend on it. The short-term gains in wealth for corporations and farmers have detrimental long-term consequences for ecosystems and livelihoods. For example, while deforestation and peat-land conversion in the humid-tropics raised regional incomes in the short term, the carbon emitted from the intensification accelerates climate change further pushing the ecosystem to crucial tipping points (Agus et al., 2020; Hergoualc'h & Verchot, 2014). Intensive agriculture further fosters soil and land degradation and reduces agricultural productivity and the ability of ecosystems to buffer natural hazards in the long term (Altieri, 2009; Leakey, 2014). For example, across SEA the conversion of upland ecosystems to intensive monocropping landscapes causes destabilization of hilltops which increases landslide risks, and widespread soil erosion which is loaded with fertilizer and pesticide residues that affect whole watersheds (Ziegler et al., 2009). Moreover, the introduction of hybrid varieties promised higher yields but the accompanying pesticide use endangers both human and soil health (Basuki et al., 2009). The Green Revolution has pushed ecosystems beyond its limits, reduced biodiversity, caused loss of traditional farming knowledge that is suitable for the specific bio-physical conditions, and profited wealthier and larger farms disproportionately more, while often encumbering smaller farms with debts (Altieri, 2009). Overall, food security in SEA is endangered by the long-term consequences of deforestation, soil erosion, land degradation, and soil infertility caused by intensification of agriculture (van Noordwijk et al., 2014).

In terms of livelihoods, Sunderland et al. (2017) review the transition from forested landscapes to agricultural systems in six tropical landscapes (Zambia, Burkina Faso, Cameroon, Ethiopia, Indonesia, Bangladesh). Their application of a socio-ecological framework on livelihoods concludes that deforestation leads to lower livelihood outcomes and loss of ecosystem services. A self-reinforcing process is theorised to lie behind these lower outcomes. In the humid tropics, the search of farmers for wealth, wellbeing and overall livelihood security is hypothesized as the root cause of the mutually reinforcing cycle of land degradation and social deprivation (Leakey, 2014). Profitable high input systems degrade soils and resources in the long term and farmers try to address failing productivity by increasing inputs once again. This spiral is incentivised by policies, subsidies and market dynamics and leads to lower levels of natural capital and decreasing yield, which is at first unrecognizable as missing natural capital is substituted by the accumulation of financial capital (Leakey, 2010). The simultaneous decline in yields, profitability and soil fertility eventually makes the farmer unable to invest into the necessary input, a dynamic that is in other interpretations referred to as the *'yield gap'* (Leakey, 2014), or a livelihood system that shifts from *'stepping up'* to *'hanging in'* (Dorward et al., 2009). Cash crop booms can accelerate the dynamic and while temporarily enabling smallholders to persist or even flourish solely on sub-livelihood sized farms (Rigg & Salamanca, 2017). Booms stimulate intensification and specialization in agriculture, usually triggering high input use and unsustainably high levels of investment. However, these booms have shown to often have disastrous aftermaths for natural resources, communities, and households in SEA. This was the case for booms of ginger in India (Münster, 2015), cassava in Cambodia and Vietnam (Mahanty & Milne, 2016), and cacao in Sulawesi

[1] Here used synonymously used with swidden agriculture and slash and burn practices for the practice of deforestation, agricultural use and natural rejuvenation while a farm or household moves to the next plot. Actual practices may differ.

(Li, 2014). Similarly, SEA and Central Java are in the firm grip of a potato boom which is suspected to erode the natural resource base (Griffin, 2020; Scott & Suarez, 2012).

Thus, the vulnerability of smallholders to climatic variability is exacerbated by socio-economic systemic conditions which demand an agricultural system that allows smallholders to persist on sub-livelihood sized farms (Chandler & Reid, 2016; Ribot, 2013). Moreover, the intensive production systems are more sensitive to slow-onset or extreme weather events associated with climate change as specialized systems fail if bio-climatic conditions necessary for production change. This demands the establishment of alternative farming systems that can provide a resilient and profitable production system to protect both smallholder livelihoods and the natural resource base. Agroecological approaches to farming are promising alternatives to intensification (Altieri et al., 2015).

1.2.2. Pathways for transformation: suggestions from agroecology and agroforestry

In the last decades, the concept of sustainable intensification gained traction, due to unwanted environmental and social consequences of economies of scale type agricultural intensification. Sustainable intensification is generally a broad concept that does not endorse particular agricultural practices or technology but promotes the increase of farm output while fostering natural, social and human capital (Pretty & Bharucha, 2014). The concept therefore entails the transformation of agricultural production towards a more sustainable process that simultaneously preserves livelihoods. While the idea of sustainable intensification is generally ill-defined, it includes moving away from a monoculture mentality towards a more dynamic approach to farming that integrates livelihoods and sustainable practices. However, the concept fundamentally lacks assessment criteria that provide a comprehensive view on social and human wellbeing (A. Smith et al., 2017). More consistently the concept of ecological intensification strives to achieve the very same outcomes by integrating agroecological principles in farming practices (Petersen & Snapp, 2015). While sustainable intensification continues to be on the international development agenda and ecological intensification remains a concept widely unknown apart from academia, the call for a social-ecological revolution and the integration of agroecological principles in farming becomes more prominent (Norton 2016).

1.2.2.1. Agroecological principles and their potential impact

Agroecological approaches are considered a promising and more clearly delineated alternative to the currently promoted sustainable intensification as well as traditional swidden practices (Franzluebbers et al., 2020; Nicholls & Altieri, 2018; Norton, 2016; Tanner et al., 2015). Agroecological farming system is a summery term that encompasses agricultural practices that operate close to characteristics of the local natural environment or ecosystem (Rudel, 2020). Agroecology offers new pathways to achieve a synergistic and interrelated set of goals of socio-economic development, ecological sustainability, and food sovereignty by blending indigenous knowledge systems with modern technologies adapted to local ecosystems (Altieri, 2009). Principles encompass the heterogeneity of crops and breeds, diversification of land-use patterns, a maximisation of ecological (e.g. predator-prey) or production based (e.g. complementary or cascading production cycles) interactions (i.e., synergies), usage of closed energy and material cycles (e.g. manure as fertilizer input), optimisation of nutrient availability for crops and animals, and landscape scale ecological management in cooperation with other farmers to preserve ecosystem goods and services (Bonaudo et al., 2014; FAO, 2018). The latter element emphasizes the social dimension of agroecology, it's emphasis on cooperation, networks, knowledge exchange and the implicit connection to social movements, and questioning power-relations and hierarchies in social-ecological systems (Méndez et al., 2013; Rosset & Martínez-Torres, 2012; Wezel et al., 2009, 2020). Farming practices reflect these principles by adopting diversified mixed cropping, intercropping and poly-culture strategies with crop rotation, green manure or cover crops in low input systems that are usually combined with agroforestry or livestock keeping completing the on-farm nutrient cycle. Agroecological approaches to land management include conservation agriculture, i.e., the reduction or avoidance of tilling and the practice soil and water conservation (i.e., terracing, contour farming, soil bounds, mulching) to reduce soil degradation and erosion (Altieri & Nicholls, 2004; Amekawa et al., 2010; Giller et al., 2015; Wezel et al., 2014).

Agroecological practices have shown to produce high yields, while having higher water use efficiency, and being less prone to crop failure as compared to intensified monocropping (Altieri, 2009; Jat et al., 2020). D'Annolfo et al (2017) synthesise the findings of 17 peer-reviewed journal articles to estimate effects of agroecology on social and economic performance. By and large, agroecological practises had positive effects on labour productivity, farm profitability and yield; results thus suggest an increase in financial capital. Altieri (2009) suggested that multi-cropping systems of small farms can have yield advantages ranging from 20-60% compared to large farms. Jat et al. (2020) find in their meta-analysis that conservation agriculture had a yield advantage of 5.8% and an increase in net economic return of 25.9% compared to conventional agriculture across South-Asia. However, in respect to income *"robust evidence of the cost-effectiveness of agroecological practices vis-à-vis alternatives is lacking and collecting it is of urgent importance"* (Sinclair et al., 2019, p. 2), which indicates a research need for sound assessment of smallholder systems.

In terms of resilience agroecological approaches may evidently increase smallholders capability to deal with shocks and allowed them to recover faster (Altieri et al., 2015; Altieri & Nicholls, 2017; Sinclair et al., 2019). Diversified systems establish cropping patterns that are less sensitive to climate variability and external farm inputs. Local farming techniques such as planting more drought tolerant local varieties, traidtional soil and water conservation practices, mixed cropping, and agroforestry contribute in sustaining livelihoods before during and after the occurrence of climate hazards (Altieri et al., 2015). Moreover, agroecological systems show higher levels of social participation which is a key component of livelihood resilience (compare Holt-Giménez et al., 2021). Among agroecological practices agroforestry is especially suited for rural smallholders of ecosystems in the humid tropics, which is increasingly acknowledged by policy makers (Altieri & Nicholls, 2004).

1.2.2.2. Agroforestry and reforestation

Given the accelerating climate crisis, reforestation has recently become a global priority. The new Forest and Landscape Restoration approach promotes the dual benefits of carbon sequestration and ecosystem-based adaptation, which aims to increase resilience against climate impacts for millions globally (Abbas et al., 2017; Colls et al., 2009; Matocha et al., 2012; Ota, Chazdon, et al., 2020; Verchot et al., 2007; Vignola et al., 2015). The Bonn Challenge endorsed by the current UN Decade on Ecosystem Restoration aims to restore 350 million hectares by 2030 Ref (Bonn Challenge 2017, UN Environment, 2019). These goals can only be achieved by integrating the livelihoods of the rural poor whose sustenance is still based on the natural resource base (compare Duguma et al., 2020). The proposed landscape-approach builds on reconciling human land-use and conservation, and thereby addresses food insecurity as well (Munang et al., 2013; Sayer et al., 2013). Reforestation improves eco-hydrological water management, prevents of depletion of soils and fosters sustainable livelihoods by protecting ecosystems goods and services that have the potential to increase crop output (Pawitan & Haryani, 2011).

Agroforestry is considered a key agricultural management technique for smallholder farmers to improve their livelihood while preserving ecosystem functions and benefits. Increasingly payment for ecosystems services schemes acknowledge the numerous benefits of reforestation and agroforestry for smallholders (fuelwood, food, animal fodder, economic safety-nets) and ecosystems (soil and water conservation, biodiversity) and aim to stimulate the increase of tree covered area in the humid tropics (Idol et al., 2011). However, evidence from reforestation programmes in Indonesia indicates that emphasis needs to be given on community use of forest products, species selection, tree density and integration in the production system to achieve effective outcomes for livelihoods (Kim et al., 2018).

Agroforestry can be implemented in a wide variety of ways amongst which trees in soil conservation (border planting), multipurpose tree species on crop lands, plantation-crop combinations, home-gardens, multi-strata systems and tree-gardens are the most commonly practiced systems by smallholders in the humid tropics (Atangana et al., 2014; Muschler, 2016; Rahman, 2017). Leakey (2010, 2014; 2005) reviewed academic literature on the effects of reforestation on livelihoods and social-ecological systems in the humid tropics. Agroforestry is considered a key agricultural strategy in this bio-climate to create highly productive cropping systems by planting of nitrogen fixating trees for soil health and animal fodder, or fruit trees and high value timber species. Not only wildlife and soil microbiomes profit from implementing agroforestry systems with nitrogen-fixating fast-growing leguminous trees, shrubs, or vines. It is a promising solution that tackles multiple problems at once. The physical properties of the planted trees prevent soil erosion, increase water retention capacity and decrease wind velocity, increase in soil nitrogen and soil organic carbon (Leakey, 2014).

Ota et al. (2020) summarize findings from 339 peer-reviewed journal articles to understand the effect of reforestation and agroforestry in the humid tropics by using the SLF framework. They find that reforestation and agroforestry increase all five livelihood capitals. However, the realization of benefits from reforestation can be limited if smallholders lack management knowledge, access to basic services and resources related to farm management (see Section 1.3). Higher levels of farming sustainability as well as increased income stability has been found in agroforestry systems across South America, Africa, and Asia (Budiadi et al., 2019; Jacobi et al., 2015; Jamnadass et al., 2011; Krishnamurthy et al., 2019; W. Liu et al., 2020; Mbow et al., 2014; Nguyen et al., 2013; Pandit et al., 2014; Quandt et al., 2019; Rahman, Jacobsen, et al., 2017; Reppin et al., 2020). For example, the implementation of agroforestry in rural mountainous Bangladesh resulted in considerable economic and ecological improvements as compared to shifting cultivation (Rasul & Thapa, 2006). Concurrently, the implementation of agroforestry has positive impacts on livelihood resilience (Lasco et al., 2014; Ota, Herbohn, et al., 2020; Prabhu et al., 2015; Saikia et al., 2017; Waldron et al., 2017). While agroforestry systems are more resilient to climate change than intensified systems and increase smallholders adaptive capacity (Lasco et al., 2014), it largely depends on how the system is designed and the density of the tree species planted (Abdulai et al., 2018; Gnonlonfoun et al., 2019).

Adoption of agroforestry practices in smallholder-systems is largely dependent on household security, accessibility to markets and information, security of land and tree tenure, labour availability, farm size, gender, management knowledge and extension service access, as well as government incentives and institutional frameworks, which highlights the necessity to investigate local socio-economic, political and environmental circumstances livelihoods face (Arvola et al., 2020; Glover et al., 2013; Grass et al., 2020). Adoption happens mostly within an ecological intensification of an existing land-use system or recovery/regeneration in a local social-ecological system context (van Noordwijk, Ekadinata, et al., 2020; van Noordwijk, Gitz, et al., 2020). These findings point to the necessity of explicating the regional and local livelihood dimensions surrounding the respective farming strategy to understand i) how socio-economic and environmental circumstances influence adoption of livelihood strategies, ii) how livelihood strategies foster livelihood outcomes, and iii) which hazards occur and how coping strategies relate to both livelihood strategies, outcomes, and ultimately resilience.

1.3. Regional context: Smallholder's agriculture and resilience in Central Java

The study investigates the challenges smallholder agriculture is facing and potential development pathways more thoroughly by narrowing its focus on Indonesia. Indonesia has recently moved to the status of a low-middle-income country. Comparably to other countries in SEA, a steady decline of rural population to 46.3% as well as the decline of the economic importance of Agriculture to 13.5% of GDP, and employment in Agriculture to 32.9% in 2015 occurred (Rigg & Salamanca, 2017). The last decades saw high population growth while the country suffered from the Asian Financial Crisis from which recovery was slow and contributed to non-sustainable agricultural intensification (Winoto & Siregar, 2016). The effect of the 2007-2008 spike in international food prices increased poverty in rural areas and profited larger land owners disproportionately (Warr & Yusuf, 2014). This historic pattern is expected to repeat itself with the latest spike in food prices following the COVID-19 crisis (Workie et al., 2020). Additionally, in the last decade the Indonesian government has endorsed policies that pushed for food self-sufficiency which favours large-scale farmers and increased pressure on smallholders who still constitute the majority of landholders the country (Hamilton-Hart, 2019; McCarthy & Obidzinski, 2017). Given that the Green Revolution has against expectations decreased farm sizes from about 3ha to 0.5-1ha per household most farmers operate on a sub-livelihood level which either necessitates livelihood diversification or intensification. The latter increases land degradation and vulnerability to climate hazards and market shocks (Rigg & Salamanca, 2017; Rudiarto et al., 2020; Turasih & Kolopaking, 2016).

In parallel to socio-economic trends, Indonesia is subject to a multitude of hazards: frequent volcanic and seismic activity, extreme weather events, seasonality, and more recently climate variability (Keil et al., 2007; Paton & Sagala, 2018). The production of all five major horticultural products of rural Java (banana, oranges, shallot, chilis, potatoes) is expected to suffer considerably from climate change impacts (Setiyanto & Pasaribu, 2021). The lowlands are subject to floods from extreme precipitation, coastal floods, and reduction of arable area by saltwater intrusion. The rural uplands of Central Java are subject to climate variability and extreme events, such as extreme rainfalls, agricultural drought, hurricanes, and extreme temperatures (Djalante et al., 2017; Keil et al., 2007). However, Indonesian smallholders have been shown to have high adaptive capacity. Livelihoods in rural Indonesia tend to be very dynamic as they adapt to market trends and shocks, using strategies of diversification, intensification in horticulture, migration and remittances according to situation the household faces and local context (Antriyandarti et al., 2013; Höing & Radjawali, 2017; Klasen et al., 2013). Therefore, a more in-depth view on livelihood strategies and their implications for livelihood vulnerability in Central Java is warranted. Apart from chosen livelihood strategies and accumulated asset bases, social and human capital constitute a crucial element of livelihood resilience and is elaborated in a regional context in Section 1.3.1.3.

1.3.1. Livelihood diversification in Central Java

Central Java is the third most populous province in Indonesia with a population density of about 1,100/km^2. About half of the population is employed in the agricultural sector (Friskadewi, 2019) while across Java gradual livelihood diversification and farm exit are common (Fridayanti & Dharmawan, 2013). While poverty is limited but prevalent (about 10-16%), the rural poor benefit from governmental yard development programmes that enhance dietary diversity (Wuriyaningrum et al., 2020), food support programs that increase resilience when complemented with staple food diversification (Utami et al., 2018), and village support funds (Tanguay 2020). Experience of the economic crisis in 1997-1999 showed that market shocks that increase input prices are sometimes not immediately felt by farmers as the shock is mediated by the previously stockpiling and subsidising government; a practice that is continued for rice until today (Sutanto, 2008). Livelihoods and farming strategies are largely determined by elevation, bio-climatic conditions, and market access. Whereas in the coastal area fisheries dominate, wetland rice is the main produce of lowland smallholders and intense horticulture constitutes the main farming style in the mid- and uplands, interspersed with livestock keeping, agroforestry systems and agrotourism projects (Iskandar et al., 2017; Nooteboom et al., 2015; Tanguay & Bernard, 2020). Each of the livelihood systems faces a particular vulnerability context that is co-determined by farming strategies and access to resources and services. The present study investigates livelihood dynamics in the uplands of Central Java.

1.3.1.1. Intensification strategies in horticulture and the production of livelihood vulnerability

The rural uplands of Central Java, and especially the fertile lands surrounding hotspots of volcanic activity, are today intensely horticulturally farmed which considerably increased local smallholders welfare (Griffin, 2020; Mariyono, 2018, 2019a, 2019c; Rahayu et al., 2018; Suminah et al., 2021). Historically, since the 1800's, tobacco was the main crop in the area. Credits for growing the annual crop were provided by Chinese tobacco traders and given the yearly harvest, financial resources of farmers were limited the rest of the year keeping them dependent on the loan system (Boomgaard, 1999). In the last decades, a slow shift to intense horticulture has taken place. The four major crops farmed are chili, carrot, cabbage and potato, all of which demand intense cultivation of the soil, and high pesticide and fertilizer input with considerable consequences for soil health (Antriyandarti et al., 2013; Griffin, 2020; Mariyono, 2017a; Tanguay & Bernard, 2020). Notably, a national potato boom caused by high domestic demand has taken hold of farmers across the Dieng Plateau in Central Java (Griffin, 2020). The boom is seen as the main cause of ending the dependence on the tobacco crop and debt relations with the traders, as it introduced a new source of income into the region in the late 1980s (Adiyoga et al., 1999). Similar developments could be observed across Asia, as potatoes promise high returns even for small farm sizes (compare Scott & Suarez, 2012). In the wake of the boom entrepreneurial farmers invested and accrued land areas between 3-6 ha (Griffin, 2020; White, 2018). However, the average operated land area size of 0.84 ha in Central Java remains small and is usually regarded as sub-livelihood level which is considered a driver for the adoption of intense horticulture (Bhattarai & Mariyono, 2016; Rigg et al., 2016; Wahyuni, 2020). For the intensive horticultural cultivation large landowners employ wage labourers for cultivation, or lease or sharecrop excess land areas (Griffin, 2020; Mariyono, 2017b). This led to the improvement of farm labourers' livelihoods with them often being able to lease or acquire small plots of land (Griffin 2020). Similar arrangements could be observed for carrots in Sulawesi (Platten, 2007) and in the highlands of East Java (Suryanata, 1994). Landowners increasingly rely on formal and informal credit to satisfy the high labour and resource demands of the potato crop (Griffin, 2020; Mariyono, 2017b, 2019b; Rahayu et al., 2018; Scott & Suarez, 2012). Next to the increase in farm profitability, the employed intensive horticulture has serious environmental drawbacks, detrimental long-term socio-economic consequences and increases livelihood vulnerability.

Griffin (2020) described the vulnerabilities of livelihoods of the Dieng Plateau in Central Java by using Doward et al.'s (2009) dynamic framework for agrarian change of smallholders. Many smallholders aim to *'step up'* by increasing investments into input and specializing on the crops (Griffin, 2020; Mariyono, 2019a; Tanguay & Bernard, 2020). While the intensive horticulture promises to raise household income with high yields at good prices, it increases vulnerability as many households are dependent on a single crop that demands high inputs in terms of seeds and labour, but above else pesticides and fertilizer (Griffin, 2020; Sodality & Adiwibowo, 2012). Thus, the farming style, but specifically the specialization on potato farming is considered highly unsustainable and projected to decrease smallholder's resilience, income and wellbeing in the mid to long term (Widayati et al., 2017). Similarly, chili, carrot and cabbage are cultivated in high input systems with considerable detrimental consequences for soil health and livelihood stability (Mariyono, 2017a, 2019a; Sumarni et al., 2012). Often the degrading quality of land as well as limitation in farming area forces smallholders to take up other livelihood activities. Further, crops are exposed to a variety to natural hazards, such as *bun upas*, freezing of early morning dew on crop leaves (Prasetyo et al., 2019), volcanic hazards (Griffin, 2019) and climate variability (Keil et al., 2007; Utami, 2017). Griffin (2020) also finds that most *'stepping out'* diversification activities of farmers centred around potato production (seed cultivation), or focused on potato and trading (pesticides, fertilizer, staple food) which increases vulnerabilities of the total food local food system as the agricultural sector focuses on a single crop. The comparatively short crop cycle (3-4 months) allows farmers to repay credit they used for high inputs but can propel them into a high debt-high interest spiral if crops fail repeatedly. Moreover, the high intensity cultivation raises concerns about levels of pesticide use, land degradation and soil erosion in adjacent watersheds, such as the Merawu watershed of Banjarnegara (Griffin, 2020; Suryatmojo et al., 2019). Widespread deforestation of the area has been shown to cause a variety of detrimental effects on smallholder's livelihoods. Soil erosion clogs downstream watersheds and contributes to the high landslide risk in the area. Communities struggle to adapt to the high levels of soil degradation and loss of soil fertility that resulted from insufficient land cover and intensive farming (Rudiarto et al., 2020). While terrace farming is a common agricultural technique to sustain top-soil layers, it seems insufficient to protect soil health given the intensity of horticultural practices (Wahono & Puspitawati, 2021). In similarly intensive farmed horticultural areas in Central Java above health-hazard threshold Nitrate levels were observed (Lowe et al., 2021). Moreover, land is increasingly divided amongst children according to local hereditary culture (Friskadewi, 2019). Those, whose vulnerability was inherited due to small farm plots, lack of financial resources for the necessary high crop input, or were subject to repeated crop failure due to vulnerabilities of the potato crop often find themselves in the *'hanging in'* situation where they have to divert to labour migration in oil palm or rubber plantations or negative coping strategies (compare Potter, 2012).

Overall, Griffin (2020) contends that the potato boom led to intensification in the area that enables smallholder to build their livelihood on comparatively small plots on land. Further, it demonstrates an alternative way of how smallholder continue to persist. This corresponds to other regional livelihood studies that find that land area increases diversification, but diversification decreased total farm productivity (Wardhana et al., 2017). Overall, Griffin (2020) concludes that the potato boom has been a successful agrarian transition from the tobacco debt system, but also introduced new vulnerabilities of natural resource degradation and resulted in a heavily divided land tenure system. Specifically, high levels of soil erosion and reduction of soil fertility have been observed in the central Javanese uplands, with the application of agroecological techniques recommended as alternative pathway to foster livelihood stability and preserve the natural resource base (Hairiah et al., 2020; Kurniawan et al., 2021; Lavigne & Gunnell, 2006; Purwaningsih et al., 2020; Sari et al., 2020; Tanguay & Bernard, 2020; Van Dijk et al., 2004).

1.3.1.2. Diversification strategies: Livestock, agroforestry and agro-ecotourism

Across large areas of Central Java, smallholder systems persist that mix livestock-crop systems with agroforestry approaches to a different extent. Smallholder timber production in Central Java is usually placed in an institutional setting and can be affiliated with agroforestry programs and associated with government owned forestry companies (Erbaugh et al., 2017). Apart from socio-economic determinants, complex regulatory frameworks co-determine the adoption of smallholder tree planting in the region (Maryudi et al., 2015). However, access to agroforestry and reforestation is often limited by lack of capital, knowledge and complexity of regulations (Maryudi et al., 2017; Rahman, Sunderland, et al., 2017)

Central Java province has a green economy policy, but due to progressive de-centralization the variety of programmes belonging to this policy are implemented differently across regencies and districts (Setiadi, 2017). The green economy programme includes several policy programmes that promote the preservation of natural forests, reforestation, and the establishment of agroforestry systems to reduce degradation of natural resources. The promoted community forestry programmes have been crucial in increasing financial returns of forestry systems (Irawanti et al., 2014; Takahashi, 2008). The transfer of property rights to local communities reduces the risk of illegal logging and deforestation (Patunru & Haryoko, 2015). The green economy programmes further interlink with food security and diversification programmes, tourism partnerships and human resource development to implement a sustainable and climate resilient development (Setiadi, 2017). However, decentralization efforts that include redistribution of public land to communities may be in conflict with national and regional climate resilience development programmes that build on forestry (Resosudarmo et al., 2019). Implementation of agroforestry techniques in smallholder systems is fostered by the distribution of seedlings for trees (mostly teak - *Tektona Grandis L.f.*, acacia - *Acacia mangium Willd.,* sengon - *Paraserianthes falcataria*, calliandra - *Calliandra calothyrsus*, pine, coffee - *Arabica* and *Robusta*, tea and different fruit trees), as well as workshops for capacity building provided by government forestry and agricultural extension services (Fujiwara et al., 2018; Iskandar et al., 2017; Maryudi et al., 2017; A. Pratiwi & Suzuki, 2017; G. E. Sabastian et al., 2019; Tanguay & Bernard, 2020). Low-income segments of agroforestry workshop participants were especially likely to switch farming practices. Thus the distribution of seedlings has significant implications for inequality (Nooteboom et al., 2015; Pratiwi & Suzuki, 2017). However, larger and economically better-off farmers with higher social and human capital are more likely to adopt timber focussed management practices that centre less around multi-purpose tree species (G. Sabastian et al., 2014).

In Central Java, small-scale forests and agroforestry systems are highly complex, and differ widely depending on topography and socio-economic conditions (Fujiwara et al., 2018). Sabastian et al., (2019, p. 608) describe the diversity of agroforestry practices and its purposes in Central Java:

> *"Tree and non-tree crops are grown from natural regeneration and planted seedlings in fields or along the contours in dryland systems (tegalan), home gardens (pekarangan) and woodlots (hutan rakyat). These trees serve a number of purposes, including timber production, boundary demarcation, shading understory crops, protection against erosion, shelter and insurance during periods of scarcity."*

Thus, a variety of agroforestry types exist in central Java (home-gardens, fruit and/or timber tree plantations, cropping in forest understory, crop field bounds for erosion control) with two main categories of cultivation (integral/rotational, and integral/permanent) (Rahman, 2017; Tanguay & Bernard, 2020). Agroforestry systems have been shown to increase overall economic performance of the farming systems compared to single crop or intensified systems (Rahman, 2017). Smallholder systems often combine agroforestry elements with coffee, tea or chili production. The tree elements are resilient against pests, contribute to soil health, and control soil erosion (Hairiah et al., 2020; Purwaningsih et al., 2020; Tanguay & Bernard, 2020). Agroforestry systems are less vulnerable to climate variability and tree elements function as economic safety net where windfall profits can be gained by periodical harvesting or when households fall on ill-times (Inoue et al., 2003; Nooteboom et al., 2015). Therefore, the implementation of agroforestry systems in the area is likely to increase climate resilience and robustness of the household against market shocks.

Livestock-crop systems are often intertwined with agroforestry practices in upland Central Java. Cut and carry systems provide protein-rich feedstuff for confined livestock from the agroforestry system, often by drawing on leguminous fodder trees. Smallholder systems that integrated tree elements with crops have been observed to have higher income than those with tree elements parcelled separately or co-located to monocropping (Seruni et al., 2021). Livestock, and especially goat keeping constitutes an important share of income for some livelihood types in Banjargegara (Umaya et al., 2020). However, the analysis of Sugiarto and Ahmad (2015) found in their sample that 71% of income is sourced from other income streams, and that farm size and income correlated which suggests the importance of cash crops, and inequality of income which depended on other livelihood activities, or off-farm work. However, smallholders who invested in trees and livestock created an asset base that fostered their livelihood stability while dealing with crop failure or other environmental hazards or market shocks (Nofrita & Krol, 2014).

Frequently, other rural transformations can be observed in Central Java. First, rural community-based tourism has become a viable alternative for off-farm income. In Banjarnegara Regency and especially the Dieng Plateau it is based on the history of the Ancient Mataram Kingdom (Effendi et al., 2020; Prasetyo et al., 2019; Sunuantari, 2017). Similar projects exist across Central Java, for example the connection of ecotourism and community forestry (Respatiadi, 2016), or local value chains of indigenous produce (Wibowo et al., 2019). Generally agro-ecotourism projects are expected to significantly contribute to the regions development and overall household welfare (Fikriyyah, 2017). Second, households rely increasingly on remittances of household members who work in urban centres (Semedi, 2012). As in other parts of Indonesia (and generally SEA) off-farm work led to a feminization of agriculture and a change in farming strategies and customs and thus which highlights the importance of researching the gender-migration-smallholder nexus and the effect of cash rich but labour poor remittance landscapes on rural livelihoods (Mulyoutami et al., 2020; compare Rigg & Salamanca, 2017; Semedi, 2012).

1.3.1.3. Livelihood resilience in Central Java, a social perspective

Human, social, and political capital constitute a crucial part of resilience towards climate change in Central Java. For example, instead of proximity to markets alone, education determines market access and livelihood improvement for smallholders in many urban-rural intersections (Astuti & Handayani, 2020). This is particularly concerning, given that the rural poor are often directly and indirectly excluded from access to information and knowledge, either by their 'hanging in' (Dorward et al., 2009), or by political and socio-economic conditions as was the case in West Java (Yusup et al., 2016).

Further, community networking and exchange of knowledge and best practices has been key in adaptation to environmental hazards (Artiningsih et al., 2016). Local knowledge helps preparing for disasters (Griffin & Barney, 2021) and the preservation of natural resources (Nurfahmi et al., 2018), but also has a meaning for the community beyond adaptation as it connects households in an effort to foster food security (Friskadewi, 2019).

Many communities profit from agricultural extension services which contribute crucially to livelihood sustainability by introducing new or more sustainable farming technology, strengthening access to services, and fostering capacity (Mustapit et al., 2019). Suciantini et al. (2020) show that in Banten Province the ratio of agricultural extension officers and farmers groups to rice fields was crucial for improved livelihood development. Utami (2017) noticed a lack of adaption action in rural Java, where community resilience could be enhanced by strengthening social, political and cultural capitals by achieving synergies with the ongoing decentralization process of the government. Similar effects have been found in Wonosobo, where increasing social capital and community engagement precipitates capacity building and climate resilience (Wibowo et al., 2021). This is corroborated by Utami et al. (2018), where community members of rural villages in Java showed higher levels of political participation, which in turn was related to increased giving to other households.

1.4. Research objective and case study introduction

To empirically investigate different livelihood strategies in the context of evolving smallholder agriculture and socio-ecological changes, this study further narrows its focus on two villages in Central Java. Some evidence and anecdotal observation suggest that two distinct farming systems exist with implications for the performance of the social-ecological system: intensified horticulture in the hamlet of Penanggungan II (village of Penanggungan) and livestock-crop systems with agroecological elements and agroforestry in the adjacent hamlets of Tamansari and Wanasari (village of Leksana) (UGM 2017).[2] Notably Sari et al (2020, p. 8) report a decrease in potato production from 4-5t/ha a decade ago to 2-3t/ha recently and the path dependency the high input – high profitability system has for farmers in Penanggungan. The villages are located in the Merawu watershed, one of 15 critical watersheds prioritized by the Indonesian government due to high levels of soil erosion from intensive upland farming. Soil erosion diminishes soil fertility at the farm level but also impacts the downstream hydropower generation and increases local landslide risks in the area (Sari et al., 2020). The hydropower company PT. Indonesia Power conducted workshops on agricultural techniques and soil erosion prevention in agriculture in Tamansari in 2009, whereas Penanggungan did not receive any such guidance. Recent evidence suggests that households in Leksana are more aware of environmental consequences of their farming strategy and rely on local and indigenous knowledge systems that is related to agroforestry (Hobo et al., 2020; Sari et al., 2020).

Given their different characteristics, the two systems are expected to exhibit different levels of livelihood resilience, income, diversification of assets, coping strategies and land degradation. To obtain a preliminary objective impression on the development of land-use in the recent years, SDG Indicator 15.3.1 *Proportion of land that is degraded over total area* was investigated. Calculation was done with the Trends.Earth 1.0.2 algorithm (Conservation International, 2018) in QGIS 3.10 (QGIS Association, 2021), using satellite data between 2001 and 2018 from the UNCCD and EU JRC datasets. Land cover differences were assessed in a 3 km buffered zone surrounding the two hamlets. Classification of land degradation was assessed in a 250m grid applied in the algorithm, which caused the area to differ marginally with a total buffer area of 28.15 km^2 surrounding Leksana, and 28.2 km^2 surrounding Penanggungan. The villages belong to two different districts within the Banjarnegara province and are approximately 8.2 km apart in linear distance (or roughly 30 min by car) and do not differ significantly in their elevation and precipitation.

Figure 1 shows land cover in 2018 (left) and categorizations of the applied algorithm (right). In the area surrounding the hamlets of Tamansari/Wanasari 77.68% of the area improved, whereas 17.07% remained stable and only 5.25% degraded. Contrarily only 15.72% of the area surrounding the hamlet Penanggungan II improved, whereas 58.95% remained stable and 25.33% degraded. Soil organic carbon content was estimated by the algorithm surprisingly similar with 201.86 t/ha in the former and 211.94 t/ha in the latter area (average across all land-cover classes), which might stem from the suspected higher use of fertilizer in Penanggungan (compare Anda & Dahlgren, 2020). Table 1 provides an overview on findings from the analysis of satellite imagery.

[2] For simplification only the villages are referred to below.

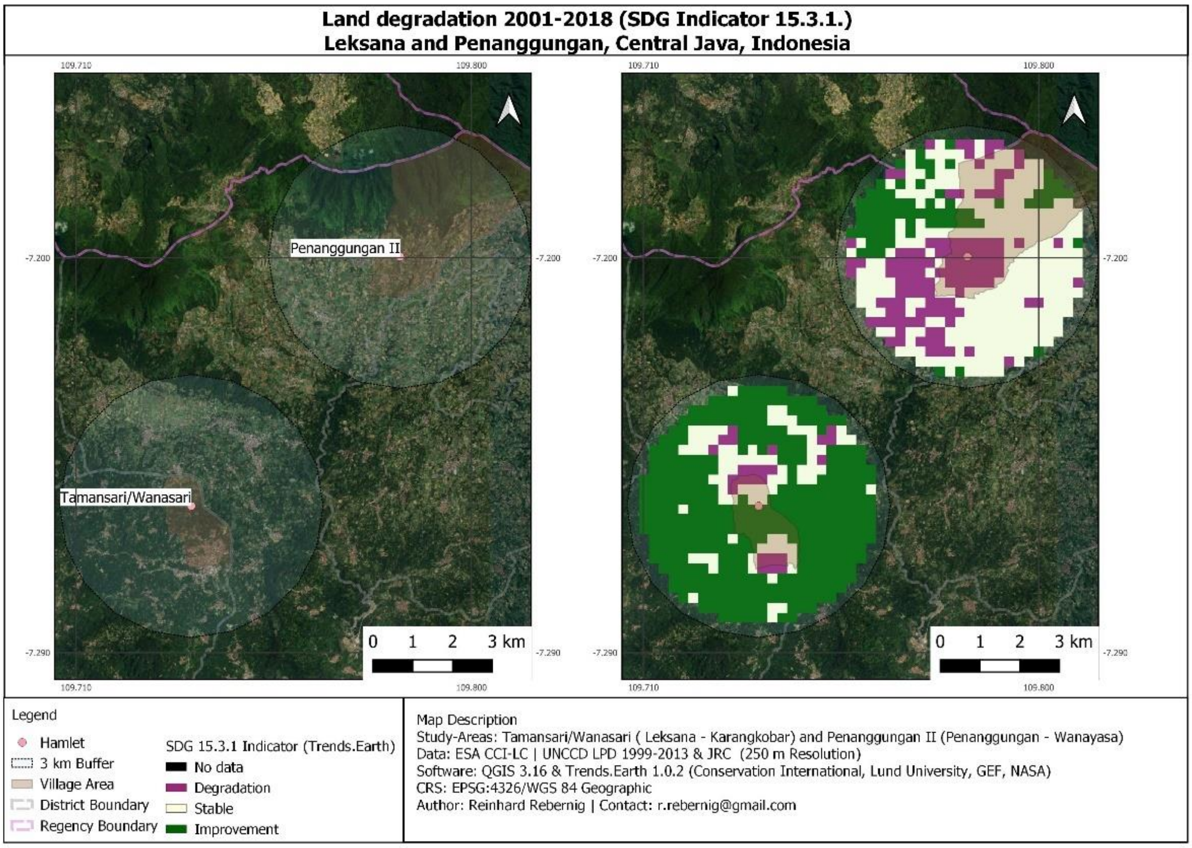

Figure 1: SDG Indicator 15.3.1. in a 3km buffer zone surrounding Leksana and Penanggungan. Own illustration.

Table 1: Land cover and soil organic carbon change in a 3 km buffer zone surrounding Leksana and Penanggungan

	Leksana			Penanggungan		
	2001	2018	Change (percent)	2001	2018	Change (percent)
Soil organic carbon [t/ha]						
Average*	201.86	204.75	1.43	211.94	213.94	3.30
Tree-covered area	*206.86*	*206.89*	0.01	222.59	227.35	-2.14
Grassland	*199.87*	*199.88*	0.01	211.87	211.68	0.09
Cropland	*199.59*	*202.54*	1.48	201.40	201.43	-0.02
Artificial area	*206.35*	*206.35*	0.00	NA		
Total [t]	*573,393.29*	*577,399.30*	0.70	602,646.67	603,306.50	0.11
Land cover change [sq. km]						
Tree-covered area	15.65	18.42	17.72	14.42	14.72	2.14
Grasslands	3.39	3.02	-0.37	3.57	3.45	-3.45
Croplands	8.99	6.59	-2.40	10.23	10.05	-1.81
Artificial area	0.12	0.12	0.00	0.00	0.00	0.00
Total [sq. km]	*28.15*	*28.15*		*28.22*	*28.22*	
Indicator (percent)						
Land area improved			77.68			15.28
Land area stable			17.07			59.39
Land area degraded			5.25			25.33

**average across land cover classes considered (tree covered area, grasslands, croplands, artificial areas)*

The results obtained from satellite imagery validate preliminary findings and provide an objective justification for further inquiry into differences of farming systems, livelihood diversification and household resilience.

1.5. Research hypotheses and questions

Following the introductory remarks above, the overall research interest of this study was to understand the outcome of distinct livelihood strategies in the context of evolving smallholder agriculture and socio-ecological changes in Central Java. This research interest was further specified in the following research questions:

- RQ1: *What are the main differences between the villages in income and farming?*
  - RQ1-SQ1: *Which livelihood strategies can be identified?*
  - RQ1-SQ2: *What are the different motivations for taking up a specific strategy?*
  - RQ1-SQ3: *How can differences in income between these strategies be explained?*

The first research question and respective sub-questions sought to delineate differences between villages and identify dominant livelihood strategies. Individual differences in motivations were investigated given the apparent differences in village associated farming styles. Finally, differences in income between these strategies were explicated to respond to the research need of thoroughly assessing agroecological farming systems. RQ1 can also be phrased as working hypothesis **H1: Households which practice agroecology have higher income,** and is based on reviews that identify positive effects on financial capital (compare Altieri, 2009; D'Annolfo et al., 2017; Jat et al., 2020; Ota, Herbohn, et al., 2020).

The second set of research questions investigated livelihood resilience:

- RQ2: *What is the level of resilience of the identified strategies?*
  - RQ2-SQ1: *What is an appropriate measure for validating the resilience indicator?*

The second research question and sub-question sought to first establish first a reference framework for assessing resilience, second to explicate resilience of the different livelihood strategies, and third to validate them with other household measures. Given the evidence of agroforestry increasing livelihood resilience, working hypothesis **H2: Households which practice agroecology have higher livelihood resilience** was adopted (compare Lasco et al., 2014; Ota, Herbohn, et al., 2020; Quandt, 2018; Quandt et al., 2019).

Finally, the third research question and sub-question focus on shocks and respective coping strategies in connection with the livelihood strategies:

- RQ3: *Which shocks were relevant to the households and what were usual coping strategies applied (last five years)?*
  - RQ3-SQ1: *Have the identified strategies applied different positive or negative coping strategies?*

As corresponding working hypothesis **H3: Households that practice agroecology are more likely to have positive coping strategies** was adopted given that evidence suggests the use of trees and livestock as saving assets for emergency cases (compare Section 1.2.2 and Sections 1.3.1.2 and 1.3.1.3). Positive coping strategies draw on buffer and adaptive capacities and contribute to maintaining the essential functions of the household. Negative coping strategies erode the capacity of the household to withstand future shocks by depleting resource stocks and buffers. T

1.6. Outline of the thesis

Section 1 introduced the socio-economic context of smallholders in SEA and Indonesia, climate impacts, livelihood strategies of intensification and agroecology and their implications for vulnerability and resilience. Further, the local context and study area was introduced, and guiding hypotheses and questions listed. Consecutive Section 2 reviews conceptual approaches and presents the conceptual framework applied in the present context. Section 3 translates the conceptual approach into an analytical framework by using a livelihood resilience indicator system. Next, Section 4 elaborates the fieldwork conducted in Summer 2018 and the applied Methods. The thesis commences with results (Section 5), discussion (Section 6) and conclusion (Section 7).

2. Conceptual framework

To frame the research objectives and questions conceptually, this chapter introduces in detail the foundations and development of the sustainable livelihood approach (Section 2.1), and the concept of livelihood resilience in smallholder social-ecological systems (Section 2.2). It further provides a conceptual integration of the sustainable livelihood framework and livelihood resilience in the context of social-ecological systems (Section 2.3).

2.1. The sustainable livelihood framework

The present research adopts the Sustainable Livelihood Framework (SLF) developed by DfID and applied widely in international development research and institutions (DFID, 1999; Scoones, 1998, 2015; Zhang et al., 2019). The academic fields and adjacent policy areas of farm profitability analysis, vulnerability assessment in climate adaptation, and – importantly - the recently demanded social turn in resilience assessment emphasize the (smallholder-) household as an observational unit for which the SLF provides an eclectic framework for analysis (Tanner et al., 2015). Focusing on the concerns of economically disadvantaged people, it has been researched and used by governments and non-governmental organizations alike as it provides for the identification of entry points in efforts to change rural livelihood systems. Thus the SLF can be considered an intervention based approach (Zhang et al., 2019).

2.1.1. History and conceptual elements

The idea of sustainable livelihoods was first described in the 1987 Brundtland commission report and further mentioned in the 1990 Human development report (compare Borowy, 2013). Chambers and Conway (1992) adopted the idea and specified definitions and key principles in their seminal paper on the Sustainable Livelihoods Approach (SLA) (Small, 2007). The relation with livelihood resilience is implied in the original definition of sustainable livelihoods (Chambers & Conway, 1992, p. 7):

> *"A livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base."*

The definition is still relevant today and hints at the ability of a household to withstand shocks, or in other words: resilience (Ifejika Speranza et al., 2014).

The idea was well received and further discussed by Scoones (1998), Farrington (2001), and Carney et al. (2003). The livelihood approach was developed as an actor-oriented perspective in development studies, emphasising access to resources and services, and the agency of the individual. Agency refers to aspirations, ambitions and solutions to problems and the ability to integrate experiences into their livelihood strategies (De Haan, 2012b). As De Haan (2000, p. 349) elaborates: *"Human agency enables man to reshape social conditions* [...]. *Agency is embodied in the individual but embedded in social relations, through which it can become effective"*. The concept of sustainable livelihoods thus builds on the work of Amartya Sen (1993) on entitlements and capabilities and the theoretical background of human development (Brown & Westaway, 2011; UNDP, 2019). It acknowledges the context of the lives of the economically disadvantaged, their strategies to overcome, and the institutions they confront. Hence, it refocuses effective policies on enabling the poor to organise effective livelihood strategies (De Haan, 2012b). It puts a focus on access in the sense that *"access is the process that brings stakeholders from endowment to entitlement"*, explain Geiser et al. (2011, p. 317; as cited from De Haan, 2012b).

Based on Scoones (1998) framework for analysis, the British Department for International Development (DFID, 1999) developed the widely cited Sustainable Livelihoods Framework (SLF) that was adopted and adapted by a number of different development agencies and institutions (e.g. the World Bank, the Society for International Development (SID), the United Nations Development Program (UNDP), Oxfam, and Care International (De Haan, 2012b; Small, 2007; Zhang et al., 2019). The sustainable livelihoods approach and the widespread adoption of the SLF comprised a paradigm shift in development research, where the focus shifted to entitlements and capabilities and from 'earning an income' towards 'making a living' (De Haan, 2012b; Scoones, 2015). Compared to the mostly top-down, technical and infrastructural approaches to rural development promoted and implemented in the previous decades, the normative principles of the livelihoods approach as set out by DFID (1999) and revised by Carney et al. (2003, p. 15) championed a distinctly more social perspective on development as they were people-centred, empowering, responsive and participatory, and sustainable. Operationally, these normative principles are addressed in multi-level, holistic and disaggregated analysis that is conducted in long-term, flexible partnerships which are facilitated in participatory development research and interventions (Morse & McNamara, 2013).

The acknowledgement of agency was accompanied by the expectations that participatory tools and bottom-up approaches are more effective in alleviating poverty, hence the introduction of the SLF as fitting framework to assist the poor in a pro-active, empowering, and self-help engaging way (De Haan, 2012b; Scoones, 2015). The concept relates to the multidimensionality nature of poverty and differs from classical economic analysis as a systems-thinking perspective.

It includes livelihood capitals that are subject to a vulnerability concept and form, under the influence of influencing socio-economic structures, strategies which build livelihood outcomes, such as food and income security, health and well-being, and improved socio-economic status (DfID, 1999). The SLF unfolds its holistic view on livelihoods thus through these five crucial elements:

- *Livelihood capitals* offer an eclectic perspective on the many dimensions of capabilities, assets and endowments, as well as access to services a livelihood consists of. The initial five capitals (human, social, natural, financial, physical) are at times expanded to accommodate assessment specific needs (e.g., agroecological or political perspective) (DFID, 1999; Scoones, 2015; Zhang et al., 2019).
- *Livelihood strategies* are a deliberate set of actions to 'make a living' that build on livelihood assets and endowments, socio-demographic characteristics as well as access to markets, credit, and services. People build their livelihoods with activities and choices aiming to achieve their livelihood goal (DFID, 1999). The basis for this are all combinations of livelihood assets which affect the capacity of rural households to develop successful livelihood transition and diversification (Bhandari, 2013). Scoones (1998) gives examples of various livelihood strategies: agricultural intensification (increasing productivity per area unit), extensification (putting additional land under cultivation), diversification (development of off-farm activities), and migration (compare Ellis, 1998).
- *Livelihood outcomes* are the basis as well as the direct and indirect, intended and unintended consequences of livelihood strategies (DFID, 1999). Different livelihood strategies are likely to be associated with different livelihood outcomes, such as improved income, resilience, food security and wellbeing, or reduced vulnerability, that in turn influence the building of the asset base which again influences the choice of livelihood strategies (De Haan, 2012b; Scoones, 2015).
- *Vulnerability context* describes effects of the environment that are potentially endangering to the respective livelihood. This includes environmental hazards, such as climatic variability, extreme events or slow-onset events and a long-term change of climatic conditions (Serrat,

2017). Further, market shocks, like sudden change in national macro-economic strategy and increase in agricultural imports may threaten the profitability of the rural smallholder agricultural production model. Impact of long-term trends like decreasing prices of agricultural goods caused by increased productivity of larger farms and technological innovation may render smallholder-farms unprofitable which are unable to adapt their production model accordingly (FAO et al., 2019). The vulnerability context may lead households to shift their strategy from market participation to subsistence farming and eventually push them to remain caught in a poverty trap (Barrett, 2007), which corresponds to Dorward et al.'s (2009) 'hanging in'. Vulnerability is not nature-made but societally co-produced (Ben Wisner et al., 1976). It may be caused by lack of access to certain assets, particularly by social exclusion, degradation of the natural resource base and lack of physical capital (e.g., infrastructure and access to water resources and health and educational services). Vulnerabilities may be addressed by short-term coping or long-term adaptation, according to the individual household livelihood strategy. However, evidence suggests that especially social capital may serve to alleviate vulnerability (Bohle & Münchener Rück-Stiftung, 2007).

- *Transforming Structures & Processes:* The utilization of assets is situated in surrounding formal and informal transforming structures or processes. Local cultures, norms, communal resource use rules and informal power relations, as well as the local and national political context and relevant policies may influence livelihood decisions. Further the local and national market environment, offering different opportunities may shape income diversification strategies. A reverse-causality link between social capital and local structures and processes is suspected on the community link (De Haan, 2012b; DFID, 1999; Mensah, 2011).

The major advantage of the SLF is that researching poverty in international development is supported with a well-structured approach, which is focusing on understanding livelihoods at micro-level without neglecting regional structural socio-economic conditions and historical path dependencies (Zhang et al., 2019). The scale (researching smallholder farming systems or including market, communities and the biophysical environment) and border of a system plays a crucial role in the assessment of livelihoods. The criteria for assessing the systems differs by the scope of the study and may include target group or topic specific methods (e.g. the gender analysis, undernutrition, environmental degradation) (de Haan, 2017).

However, while the SLF offers a common conceptual start of analysis, the concept struggled with a variety of operationalizations, owing to its contextual nature (Scoones, 2015). Since the livelihood approach analyses livelihoods in widely varying geographical, socioeconomic and bio-physical environments its application is often context dependent and produces a multitude of hardly comparable studies. Methodological issues in aggregation often lead to misinterpretations. The future of studies in the sustainable livelihood approach lies in generalization and comparison via methodologically-sound qualitative meta-analysis of individual livelihood assessments compare (De Haan, 2012b). While the SLF chronically suffers from incomparability above local contextualization's (Scoones, 2015), livelihood studies that build on the SLF have the advantage (and disadvantage) that the diversity and complexity of agrarian lives is captured in distinct categories (Batterbury, 2016).

2.1.2. Theoretical background, critique, and alternatives

The SLF is originally envisaged to not only statically assess livelihoods but also capture their dynamics. Given that the concept is often used without placing it in larger theoretical background, e.g., any particular theory of social or economic change in development, while drawing elements from several of them, there exists a lack of consistency in the application of the SLF (Small, 2007). Small (2007) in her criticism of the SLF argues that it needs to relate to current academic approaches when applying. Likewise, good livelihood analysis situates micro-scale processes of the household with larger structures that influence assets, access, and opportunities (Scoones, 2015). Generally, the approach is located between the agency versus structure debate inherent to international development debates (Small, 2007). The SLF is an intentional and action oriented approach to understand livelihoods and to guide limited government resources to support an immanent local development background (Morse & McNamara, 2013). The SLF as diagnostic tool aims at either identification of livelihood patterns or maximising the effectiveness of development interventions by identifying leverage points for change (Allison & Horemans, 2006; Tao & Wall, 2009). As diagnostic tool alone, Morse and McNamara (2013) suggest that the approach can also accommodate bottom-up development pathways. However, the dichotomy of "already developed" and "yet to be developed" implied by grading livelihoods along a defined scale has been a major point of critique of the SLF, interpreting it as continuation of colonialist and post-war capitalist thinking (Escobar, 1992; Schuurman, 2000, p. 17; Sidaway, 2007, 2007, p. 17; as cited in Morse & McNamara, 2013). In general, development cooperation cannot boast a successful track record (Morse & McNamara, 2013). Indeed, approaches of post development and anti-development have fundamentally questioned the assumptions of the development endeavour and the framing of livelihood capitals often provokes criticism (Rahnema & Bawtree, 1997; Simon, 2006; as cited in Morse & McNamara, 2013). The focus on the economic side of livelihood activities was initially criticized by Polanyi (Polanyi, 1977), who saw economics of livelihoods as socially, culturally and historically embedded, and deemed such analysis necessary to gain full understanding of people's choices and behaviour. Therefore, poverty was no more seen as only a matter of income and physical resources but as a multidimensional phenomenon. Another stream of criticism emerged from critical social sciences, informed by the thinking of the Frankfurter Schule in the 1930s. Its perspective on oppressive power hindering societal transformation clashed with the bottom-up agency focus of the livelihood system approach. The reduction of people's lives to the exchange of capital (be it socially, human or natural and physical) was criticized as neo-liberal (De Haan, 2012), as it made the people themselves invisible (Morse & McNamara, 2013). Concomitantly, the absence of the explicit mentioning of power relations was another major criticism of the livelihoods concept (Small, 2007). Livelihoods exert and are subject to hierarchical power relations that relate to their resource claims and access to services (Carney et al., 2003; De Haan, 2012b).

Several alternatives, extensions and variations exist of the SLF. Livelihood strategies build on previous livelihood capitals and can enhance or diminish them. The approach of Dorward et al. (2009) to assess livelihoods uses a more dynamic framework for agrarian change of smallholders. The accumulation and expansion of assets and productivity is conceptualized as *'stepping up'*. On the other hand, many farmers use accumulated wealth to diversify their income sources (*'stepping out'*). Last, and most critically, those usually caught in poverty traps (compare Barret 2007), are *'hanging in'* by maintaining their livelihoods with strategies that are not able to propel them to a higher socio-economic welfare level. Given that livelihoods are based in a socio-economic and political background, Mensah (2011) reconstructed the SLF in response for insufficient micro to macro-economic links. The Community Capitals Framework was an adaptation of the SLF, which included the political and cultural context in the aggregate context of communities (Emery & Flora, 2006). Further, as livelihood activities may endanger the natural resource base; alternative livelihood approaches aim to replace these activities with lower impactful ones that have at least equivalent benefits (Wright et al., 2016). For forest-based social-ecological systems Kalaba (2014) developed a specific livelihood framework that is based on the DPSIR policy analysis model and integrated direct and indirect drivers of land use change.

In conclusion, the sustainable livelihoods concept developed over the years into a multi-objective and interdisciplinary approach and is used by academia and policy in international economic development and environmental conservation (Zhang et al., 2019). From a pragmatic perspective, the SLF can be considered as a theoretically grounded, analytically helpful, and practically applicable framework. The theoretical grounding is usually based on Amartya Sen's Capability approach and the grand theory of human development in international cooperation (Farrington, 2001; Zhang et al., 2019). In the last decades, the concept found application in a variety of poverty and rural development related areas: farm profitability analysis, vulnerability and climate change adaptation, security and poverty reduction, land use change and sustainable farming, energy consumption and renewable energy technology and livelihood resilience against climate change (Zhang et al., 2019). A special emphasis in literature is given on livelihood strategies and their connection to livelihood resilience, amongst which diversification of asset base, endowments and access receives special attention.

2.1.3. Livelihood strategies

Amongst livelihood strategies, intensification and diversification receive special attention from scholars as they majorly influence rural transformation, agricultural productivity and smallholder's welfare level (Zhang et al., 2019).

The extent to which a livelihood is diversified can be determined by measuring its asset base, endowments and entitlements, capabilities and access to services, and income sources (DFID, 1999). The diversification of the income portfolio is a subcategory of financial asset diversification and can be categorised in the primary categories of farm and off-farm activities or income sources. It is often the main part of livelihood diversification assessment in quantitative analysis. Income from farming activities include market sales and in-kind consumption of animal and crop products. Off-farm activities range from wage work or salaried jobs, rents to pensions and remittances. Investment in social activities or education can be seen as long-term asset development strategy and eventually linked to migration and remittances. The diversification of livelihood strategies may lead the household to expand into more profitable activities or withdraw vital resources from them. Human capital and labour force may be shortened by migration and household economy enhanced by remittances. Causes and consequences of diversification can be assessed by location, assets, income, opportunity and social relations. Intensification of farming can be conceptualized as a sub-category of diversification where the smallholder chooses a limited set of strategies to maximize short-term profit, often at the cost of increased vulnerability and risk (Ellis, 1998).

The vulnerability context as well as governing socio-economic structures are both major drivers for livelihood diversification in terms of risk management. Rural households can be risk prone due to internal factors such as mismanagement, or external factors such as seasonality, natural hazards, market shocks and price fluctuations. Vulnerability relates to the potential exposure to the risk of being damaged by shocks and events as well as pre-existing socio-economic conditions (M. B. Hahn et al., 2009). In general, households can either be risk tolerant and willing to invest into high input high output agricultural systems or risk averse and willing to trade off lower income for greater security. Diversification of cropping and livestock breeding are ex-ante risk mitigation or spreading strategies to minimize income loss in potentially sub-optimal bio-climatic or socioeconomic conditions whilst fostering decent levels of livelihood wellbeing at optimal conditions. The goal of diversification is to achieve a portfolio with low covariate risk between the income generating activities. However, market shocks and natural disasters may affect different assets simultaneously (Ellis, 2000).

Viewing livelihood diversification in terms of resilience offers three development pathways on how a smallholder social-ecological system can interact with system perturbations (Folke, 2006, 2016; Tanner et al., 2015). First, coping is defined as short term ex-post response to an adverse event experienced by the household. It includes consumption smoothing behaviour like using savings and food stocks, reciprocal in-kind transfer in the social network, sales of livestock, timber and other assets or wage work and short-term migration (De Haan, 2012b; Ellis, 1998). Thus, the current level of household consumption is lowered by protecting the future income generating capability, which can have disastrous effects on household nutrition levels if negative coping strategies are applied. The mid-term perspective of successful livelihood diversification includes an adaptive component of resilience. Adaptation of farming strategies and livelihood diversification is crucial to respond to current and future bio-climatic trends and socio-economic changes. Adaptation can happen in ex-ante anticipation or ex-post learnings from past events and impacts. Successful adaptation is a deliberate act, reversible and fosters resilience, whereas unsuccessful adaptation may happen out of necessity, may be irreversible and fails to reduce vulnerability (De Haan, 2012b). Adaptability is therefore a crucial component of livelihood vulnerability and resilience assessment. Livelihood strategies and diversification in turn reflect a smallholder's ability to adapt to pre-existing or changing conditions.

Third, transformative change as reaction to or anticipation of system perturbations fosters livelihood stability as the system becomes adaptable and can continuously respond to change while preserving higher levels of livelihood wellbeing.

Determinants of livelihood diversifications usually are seasonality, labour market conditions, risk mitigation strategies, crisis coping strategy, access to financial services and savings and investment strategies (Ellis, 1998, Niehof, 2004). Rural households confront seasonality as inherent feature of their livelihoods; irregular returns of labour and production outcomes have to meet continuous household consumption. To achieve consumption smoothing, this income instability can be addressed by diversifying into savings, crop storage, output sales and off-farm wage work including seasonal migration; activities which are not dependent on changing geophysical conditions on the farm. Both, seasonality and livelihood diversification are co-determined by location, time, skills, gender, education, and cultural norms (Ellis, 1998).

Evidence suggests that diversification into non-farm activities is associated with higher income and that rural development is closely related with the development of the non-farm economy (Davis et al., 2010; Salifu, 2019). Diversification is usually the choice of the poor and has heterogenous effects on the well-endowed (Asfaw et al., 2019). Increasingly, rural areas undergo a shift towards increased livelihoods diversification of smallholder-farms which includes participation in the non-farm rural economy and explains the persistence of the smallholder in SEA. This shift has serious implications for livelihood resilience towards the changing climate.

2.2. Livelihood resilience in smallholder social-ecological systems

This section leads through the conceptualisation of agroecologically determined livelihood resilience and its theoretical origins and applications.

2.2.1. Livelihood resilience: Theory and conceptualizations in the context of agroecology and international cooperation

Similar to the debate surrounding livelihood vulnerability three strands of research encompass the resilience debate (Adger, 2006; Bahadur et al., 2013; Bollettino et al., 2017; Janssen & Ostrom, 2006; Smit & Wandel, 2006; Sterk et al., 2017). Fundamentally, resilience and vulnerability are complementary concepts that overlap to a large extent when conceptualized at the household level (Gallopín, 2006; M. B. Hahn et al., 2009; Hinkel, 2011; Miller et al., 2010; Quandt, 2018). Fundamentally resilience originates in ecological systems theory and engineering and is a dynamic concept that emphasizes nonlinear change and uncertainty as continuous influence on the system (Folke, 2016; Holling, 1973; Pimm, 1984). First, the research strand of poverty and rural livelihoods is agency focussed and builds on Sen's capability approach (Adger, 2006). Further, the debate surrounding food security and marginality frequently links livelihoods and the concept of resilience. Second, disaster risk reduction (DRR) approaches resilience through the risk cycle(Ansah et al., 2019; Callo-Concha et al., 2014; Pelletier et al., 2016). While origins of the DRR school of thinking were technical, the last decades saw a turn towards the appreciation of the social co-production of resilience and vulnerability in the face of natural hazards (Bollettino et al., 2017; Tierney, 2014; Ben Wisner et al., 1976; Benjamin Wisner, 2016). A variety of conceptualizations of disaster resilience exist that are based on the livelihood approach and the five livelihood capitals (Bahadur et al., 2013; Mayunga, 2007). Given the trans- and interdisciplinary use of the resilience concept and its intrinsic connection to livelihoods, it is important to note that also in the DRR literature a focus on local agency of people in the area or situation at risk beyond mere conceptualizations of vulnerable livelihoods and victimization is endorsed (Tierney, 2014; Ben Wisner et al., 2004, p. 14). This focus on agency is one of the major reasons why in regards to livelihoods vulnerability and resilience are epistemologically non-trivially related (Gallopín, 2006). Third, climate change adaptation (CCA) increasingly focuses on livelihood dynamics, resilience and wellbeing (Carr, 2020; Kofinas & Chapin, 2009). Thus, resilience can be regarded as a 'boundary concept' between several disciplines, which also contributes too lack of clarity and multiplicity regarding the adjacent concepts of sustainability and adaptation (Brand & Jax, 2007; Zanotti et al., 2020). Recently a turn towards a deeper inclusion of the livelihood concept in resilience assessment has been encouraged that better resonates with people's daily lives (Brown, 2014; Cannon & Müller-Mahn, 2010; Tanner et al., 2015).

Resilient social-ecological systems have the ability to absorb, adapt to, or transform with a system perturbation, which makes resilience an essentially positive concept (Folke, 2016; Folke et al., 2010). Thus, resilience can be assessed statically, i.e., the ability of a system to buffer or absorb a perturbation, or dynamically, i.e., by observing adaptive and transformative behaviour of the system. Overall, resilience in social-ecological systems theory is conceptualized as the system's capacity to preserve its identity or system purpose (ibid). In general resilience can be defined as *"the capacity of a social ecological system to absorb disturbance, adapt or transform in the face of change, so that the function, structure, and feedbacks of the system continue to support human and environmental well-being"* (Goffner et al., 2019, p. 1419; adapted from Folke, 2016; Folke et al., 2010). Therefore, resilient systems exhibit the capacity to persist shocks, adapt to them or transform to be less vulnerable and more resilient, which is a more dynamic perspective than the return to an original state, or in other words a state of non-linear stability (Jones & Tanner, 2017; B. Walker et al., 2004).

Agro-ecosystemic resilience is not a neutral concept that merely depicts the ability of a social-ecological system to withstand any perturbance and keep its identity defining functions upright. First, agroecosystems are a complex "*set of interactions between different physical, biological, socioeconomic, symbolical, political technological subsystems in a certain geographical space, which converge and interact with external factors, within the framework of a productive process led by humans* " (Córdoba Vargas et al., 2020, p. 1). Naturally, the characteristic and behaviour of these systems is dependent upon human decisions that influence their formation. Córdoba Vargas et al. 2020 argue that the resilience of agroecosystems should not be reduced to a single dimension of maintaining levels of production in the face of natural hazard or market shock. On the contrary they argue that the research of equity, justice and power relations is vital to redefining questions of resilience *'Resilience for whom towards what?'* to *'Resilience to what, planned by whom and for whom?'.* This coincides with Jones and Tanner's (2017) shift in the conceptualization of resilience to the identification of root causes of vulnerability and loss of resilience. Whitfield et al. (2019) in their review of socio-ecological resilience towards the 2015-16 El Nino events across the Tropics find that SES resilience is much determined by the history of the system (hysteresis), i.e. political and economic lock-ins and path dependencies. Again, this conceptualization of resilience is close to conceptualizations of vulnerability in the Pressure and Release Model in DRR literature, which includes historic structural conditioning of present socio-economic states . This recent trends in research seem to indicate a general transition from sustainable livelihoods to resilient livelihoods which encompass a wider notion of meaning, power, difference and agency and reframe them in socio-ecological projects that aim to increase wellbeing, which situates resilience in social change research (Carr, 2019, 2020; Cote & Nightingale, 2012).

The combination of livelihood strategy and resilience assessment is motivated by a recent turn in resilience evaluation from usual community or governance unit, or social-ecological systems perspective, to integrating the sustainable livelihoods approach, as encouraged by Tanner et al. (2015) responding to the call for a social and political turn in resilience thinking (Brown, 2013, O'Brian 2011). It mirrors Scoones (2009) endorsement of complementing livelihood analysis with the concept of resilience in relation to the sustainability of the livelihoods. In fact, the concept of resilience in livelihood studies is implied in the sustainability of actor's behaviour that stabilize a system. Therefore, like the sustainable livelihood approach, resilience builds on agency and capacities (Ifejika Speranza et al., 2014). On the other hand, Small (2007) in her critique of the livelihood approach argues that the SLF can function as bridge between complex adaptive system theory and ecosystem approaches to conceptualize resilience and adaptation, which is acknowledged by Ostrom's (2009) inclusion of livelihoods (or resource users) in her general framework of social-ecological systems sustainability. Moreover, the use of vulnerability and resilience concepts in combination with the sustainable livelihood approach is argued by Joakim (2013) to inform and advance climate change adaptation research and endorsed by the Sendai Framework for Disaster Risk Reduction (UNDRR, 2015). Empirically, the assessment of livelihood resilience (Quandt, 2018) and livelihood vulnerability (M. B. Hahn et al., 2009) is both based on the SLF as are others that combine the approaches (Joakim, 2013), or do not choose to approach livelihood resilience from the social-ecological perspective (Marschke & Berkes, 2006; Obrist et al., 2010; Sallu et al., 2010). The construct of *'resilience of smallholders'* places small scale farmers and diversified livelihoods not only in the context of societal, economic and political structures but they are based on natural resources and are subject to bio-climatic conditions which leads to the conceptualization of social-ecological systems (Kofinas & Chapin, 2009). Ota et al. (2020) use the livelihood framework to review 339 articles that analyse the impact of reforestation on smallholders and find evidence that the implementation of agroforestry increases socio-ecological resilience, as well as all five livelihood capitals. However, the livelihood approach is not deemed suitable to look at the resilience of SES at a landscape level due to the emphasis on socio-economic factors (Ciftcioglu, 2017).

Livelihood resilience has been critiqued in a variety of ways. First, livelihood resilience conveniently depoliticises climate justice in the international policy discourse and may indirectly shift the burden from the polluters to those who have to adapt (Beck, 2009; Béné et al., 2012; Cannon & Müller-Mahn, 2010; Chandler & Reid, 2016). Second, it is not particularly a pro-poor concept and *"and the objective of poverty reduction cannot simply be substituted by resilience building"* (Béné et al., 2012, p. 3). However, livelihood resilience can act a lens for transformative livelihood development (Boyd et al., 2008). Moreover, with livelihood resilience a new framework for top down interventionist solutions may have been established that neglects historical and structural roots of power imbalances, inequality and poverty (Chandler & Reid, 2016; Mikulewicz, 2018; Mikulewicz & Taylor, 2020; Tanner et al., 2015). However, this is the very reason why resilience needs to be a human-rights informed approach to development (Tanner et al., 2015).

2.2.2. Agroecological resilience assessment

The present work answers the essential question of *'Resilience of what to what?'* (Carpenter et al., 2001) by defining resilience as the household's capacity to withstand any climatic and market shock without losing its essential functions and identity, i.e. at the very least the safeguarded provision of food and shelter, or the support of human wellbeing at a decent level. Household resilience assessment as applied in this thesis focuses on a portfolio of actions that foster the capacity to face any predictable and unpredictable shock or stress, in contrast to specific resilience. Beyond that, the question of *'Resilience to what, planned by whom and for whom?'* (Córdoba Varga et al., 2020) is rudimentarily included by understanding historic agrarian developments in the region and by including government interventions such as the presence of extension service, subsidies, and workshops. The latter is important as resilience is influenced by the wider social and political environment (Béné et al., 2012; Cote & Nightingale, 2012; Tanner & Allouche, 2011).

Resilience as defined in that way includes the abilities of a household to anticipate, prepare for, withstand (i.e., buffer), cope with, and recover from these shocks, and beyond to adjust to them or transform with them. The expansion of resilience beyond mere buffer capacity that guarantees the stability of the status quo to inclusion of capacity for self-organisation and capacity for learning and adaptation is justified as agroecological resilience essentially must question hierarchical power relations (Córdoba Varga et al., 2020). Ifejike Speranza et al. (2014, p. 110) implicitly recognize this when referring to *"increasing the capabilities (agency) to respond to adverse external conditions and to develop collective action aimed at changing the part of external societal structures that constrain resilience-related agency".* Thus, the normative component of resilience is emphasized by carefully distributing a variety of variables that can be attributed to social capital between the sub-dimensions outlined below (Bernier & Meinzen-Dick, 2014). Situating resilience with a firm emphasis on social capital and cross scale SES interactions allows to capture heterogeneity of rationalities and power structures (Cote & Nightingale, 2012).

Drawing on Carpenter et al.'s (2001) three dimension of resilience, Cabell and Oleofse (2012) proposed an indicator framework for agroecosystem resilience which was operationalized by Ifejika Speranza (2013), Ifejika Speranza et al. (2014) and Jacobi et al. (2018). The present work uses the translation to the household level as empirically conducted by Quandt (2018) by recognising the household as an appropriate observational unit (compare Section 3). Table 2 gives an overview of the three dimensions of buffer capacity, capacity for self-organisation and capacity for learning and adaptation as adapted for the present household-focused resilience research.

Table 2: Conceptual framework for livelihood resilience. Adapted from Ifejika Speranza (2013); Ifejika Speranza et al, (2014); Cabell and Oelofse, (2012); Jacobi et al., (2018).

	Resilience	
Buffer Capacity*	**Self-organization**	**Capacity for learning and adaptation**
Natural capital	Institutions	Shared vison
Financial capital	Cooperation and networks	Reflective and shared learning
Physical capital	Self-sufficiency of farming	Openness to change
Human capital	Opportunity for self-organisation	Functioning feedback mechanisms
Social Capital		Existence and use of local traditional knowledge
Farm diversity		Knowledge of threats and opportunities

* Includes endowment (assets/ownership) and entitlements (access to asset).

(1) *Buffer capacity* relates to the ability of a social-ecological system (here: household) and its characteristics to be able to withstand shocks. As such it contains the capacity for short term coping behaviour. From a purely theoretically perspective it is related to the origins of the resilience definition of a system being able to preserve its essential functions and identity (Berkes & Folke, 1994; Carpenter et al., 2001). It is measured by the development of the individual household assets and access to them, i.e. by the five capitals of the SLF (DFID, 1999), as conceptualized in Ifejika Speranza (2014), and operationalized as in Quandt (2018), and extended by farm diversity for agroecological systems as employed in Jacobi (2018) and inspired by Altieri et al. (2015). Farm diversity, i.e. the diversification of income, crops and livestock as well as the implementation of agroforestry or mixed cropping increases livelihood

resilience (Ifejika Speranza et al., 2014; Ota, Herbohn, et al., 2020; Sterk et al., 2017). The conceptualization of the livelihood capitals is congruent with use in the literature (compare review of Ifejika Speranza et al., 2014; and Quandt, 2018). The five categories that comprise a livelihood are conceptualized in the SLF as the five “livelihood assets”, upon which livelihoods are build and people need access to. *“The assets constitute a stock of capital that can be stored, accumulated, exchanged or allocated to activities to generate a flow of income or means of livelihoods or other benefits”* delineates Babulo et al. (2008, p. 148; referring to Rakodi & Lloyd-Jones, 2002). The terms ‘capital’ and ‘assets’ are often used interchangeably. These five assets are identified by Scoones (1998) as comprising natural (natural resources such as land, flora and fauna, water), human (skills, knowledge, health), financial (savings, ownership of livestock, remittances), physical (roads, infrastructure, equipment, tools), and social (networks and connections, membership of groups, relationships of trust and reciprocity) capitals/assets (Carney, 2003; DFID, 1999). For overview of connection between livelihood assets and farm exit strategies as livelihood transitions (compare Bhandari, 2013).

(2) *Capacity for self-organization* is defined by the ability of a household or a community to co-create society (rules, norms, values, and organisation) in order to foster resilience of the actor or system. Further it can be seen as an analytical lens on emergent systems that stabilise livelihood actors within communities. The definition of Milestad and Darnhofer (2003) on self-organisation of farmers does the request for the inclusion of power relations of Córdoba Varga (2020) justice as self-organisation can be happen from bottom-up and interact across scales with the institutional environment, which is also envisaged in the multi-layered social resilience framework of Obrist et al. (2010). Hahn and Nykvist (2017) find in their review of self-organization in social-ecological systems that self-organization (as adaptability) is often described as being intentional in ex-post analysis, but processes are shaped by actors with separate strategies and conflicting interests; this is factored in by focusing on the household level which allows for heterogeneity within groups or communities.

a. *Institutions* encompass societal norms and rules (Ostrom, 1990; as cited in Ifejika Speranza et al., 2014). In the present context, institutions are framed as market power the farmer has, by virtue of organisation within a farmers group or comparable (compare the review of Ota et al., 2020, and Jacobi et al., 2018). Institutions contribute to household’s adaptive capacity and can influence coping strategies and are a key ingredient in resilience (Bahadur et al., 2013; Cabell & Oelofse, 2012; Ostrom, 1990; Pretty & Smith, 2004).
b. *Cooperation and networks* build the foundation of social capital and can be indicated by of trust and reciprocity in terms of goods or money (Ifejika Speranza et al., 2014). These interactions form social capital which can stabilize livelihoods during crises (Bernier & Meinzen-Dick, 2014; Pretty & Smith, 2004).
c. *Self-sufficiency of farming* is less focused on a knowledge as envisioned in Ifejika Speranza et al. (2014) but more practically focused on local food and income security achieved by the household (Ansah et al., 2019; Jacobi et al., 2018), which first contributes to the household’s independence, but also enables it to contribute to the community.
d. *Political capital* indicates the actor’s perception of the ability to change the current system. It relates to the closeness of power to influence decisions at local or community level, i.e. local leadership (Kates et al., 2012). Hence, it partially addresses the criticism of Scoones (2009) and Small (2007) as well as Córdoba Vargas et al. 2020 to include power relations, as it integrates a bottom-up locality of political power.

(3) *Capacity for learning and adaptation* describes the adaptive component of a resilient system, i.e. the capacity to learn from system perturbations and adjust accordingly to the benefit of the system (Ifejika Speranza et al, 2014). The definitions merges both, the concept of adaptation (Janssen & Ostrom, 2006; Smit & Wandel, 2006) and the concept of learning in adaptive co-management (Armitage et al., 2008). In that sense the capacity to adapt can make way for successful transformation of a livelihood towards a more climate resilient state (Carr, 2019). The capacity to learn is fundamental to the concept of resilience as it enables SES actors to adapt (Sterk et al., 2017).

   a. *Knowledge of threats and opportunities* is essential for households ability to appropriately prepare for adjust to threats (Ifejika Speranza et al., 2014). Agricultural extension services are an essential source of information about expected climate change impacts and appropriate agricultural adaptation strategies (Hunt et al., 2011; Keil et al., 2007).
   b. *Reflective and shared Learning* between households within a community or outside indicates sharing experiences and best-practices, within a self-organised training or via neighbourhood interaction, which helps the household to better prepare for shocks (Cabell & Oelofse, 2012; Ifejika Speranza et al., 2014).
   c. *Openness to change* captures Ifejika Speranza et al.'s (2014) knowledge sharing and transfer capability by conceptualizing it as a capacity to learn and adapt the farming style.
   d. *Functioning Feedback mechanisms* contrasts the inter-household exchange perspective and focuses on systemic feedback mechanism that influence farming style and adaptation to but also recovery from hazards and shocks. This includes government subsidies and trainings (Ashkenazy et al., 2018), community support during crises (Bernier & Meinzen-Dick, 2014), as well as social security/insurance (Ifejika Speranza et al., 2014).
   e. *Existence and use of local traditional knowledge* enables households to prepare and respond appropriately to hazards, based on contextualized knowledge and experience (Berkes et al., 2000; Gómez-Baggethun et al., 2013; Lebel, 2013; Ruiz-Mallén & Corbera, 2013). It embodies on household level cultural memory, identity and knowledge of the ecosystem (Cabell & Oelofse, 2012; Ifejika Speranza et al., 2014).
   f. *Shared Vision* enables amongst smallholders in a community creates an enabling environment for change towards more sustainable practices and acceleration by learning of best practices (Ifejika Speranza et al., 2014; Jacobi et al., 2018; Lebel et al., 2006).

2.3. Conceptual framework: integration

A livelihood in the present comparative case study refers to the original DFID (1999) definition that was adapted from Chambers and Conway (2002). To do the recent demand for SLF based resilience assessment justice (compare Section 2.2), households are chosen as observational units as frequently used in livelihood research. The push for the livelihood perspective (Tanner et al., 2015) coincides with Rigg and Salamanca (2018, p. 41), who argue that livelihood diversity is *"best viewed and understood in household terms"*, which can be accommodated by both, the SLF and Ostrom's general framework for analysing sustainability of social-ecological system (Ostrom, 2009; Thiel et al., 2015). 2015). The present approach is theoretically situated in the tradition of human development and Amartya Sen's capability approach which is the basis for the development of the SLF (compare Section 2.1.). In the present study agroecological livelihood resilience serves as operational concept based on the theory of social-ecological systems and the SLF (compare Section 2).

As the household is chosen as observational unit it includes members that either regularly or frequently eat and sleep in the dwelling unit. Further, it includes members that, while being absent not only contribute to income (remittances) but also carry a certain formal responsibility (household head). This builds on the idea of Rigg (2007, p. 29; as cited in Griffin, 2020) that a livelihood perspective *"places people back at the centre of attention and explanation, endowing them with a degree of agency to struggle against, take advantage of, and resist or rework their political, economic, social and environmental milieu",* so that while absent, members still have significant influence on household strategies. The household perspective allows for the assessment of internal variability and differences as opposed to the dogma of homogenous communities in development research thinking (Agrawal & Gibson, 1999). This approach acknowledges the fact that indicators vary within a community or village. Further, it balances access with availability, as *"the existence of an asset does not imply that an individual is able to access that asset, thus addressing issues of power and human agency"* (Quandt, 2018, p. 258). The household is thus conceptualized as an appropriate focus lens to ascertain livelihood strategies and outcomes and coping strategies as well as the regional vulnerability context. Figure 2 presents the integrated framework for analysis.

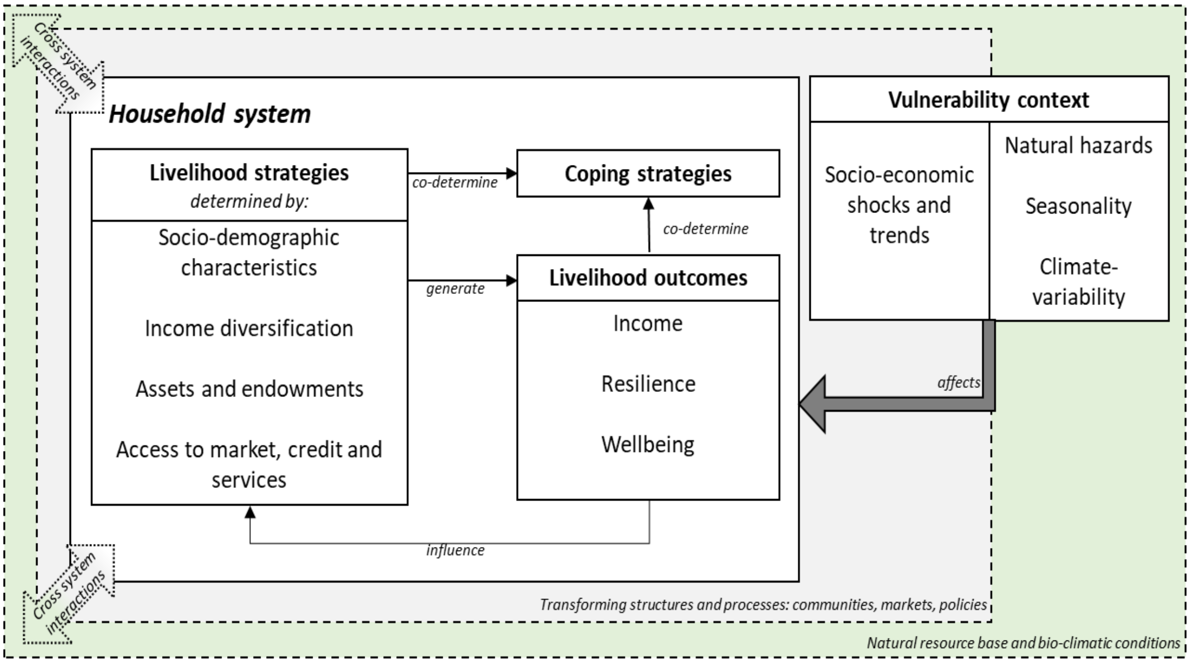

Figure 2: Conceptual framework. Adapted from DFID, (1999); Ostrom, (2009); Theil, (2015).

As the concepts of resilience and livelihood diversification overlap both conceptually and analytically due to their mutual interdependency, assessment of livelihood diversification in the present work does not use directly the usual SLF capitals. Rather the conceptual framework chooses a set of key variables that are symptomatic for differences in strategies as applied in other livelihood research, or research that connects livelihood strategies with resilience assessment in a social-ecological systems framework (Ado et al., 2019; Kuivanen et al., 2016; S. Liu et al., 2016; W. Liu et al., 2020; Marschke & Berkes, 2006; Quandt, 2018; Tittonell, 2011; Williams et al., 2018).

Livelihood strategies can be conceptualized as the necessary linkages to understand the link between livelihoods and the state of social-ecological systems in agrobiodiversity (Zimmerer & Vanek, 2016). Livelihood strategies build livelihood outcomes and prepare household for better coping eventual adaptation (Jones & Tanner, 2017; Mallick, 2019; Marschke & Berkes, 2006). Coping can in simple terms be conceptualized as a short-term version of resilience, i.e., consumption smoothing by accessing the buffer capacity (Ifejika Speranza 2014). Moreover, livelihood strategies offer a more dynamic picture that can be well linked to livelihood resilience assessment (Scoones, 2009), and in combination with coping strategies provides a glimpse into how households respond to the vulnerability context. The cross-scale perspective is essential for ascertaining livelihood resilience as it allows to identify interactions between livelihoods, communities and the socio-economic, political and natural environment (Bahadur et al., 2013; Córdoba Vargas et al., 2020; Mensah, 2011)

3. Analytical framework

This section outlines the analytical framework which is then implemented by the empirical strategy of Section 4. It explains the translation of the concepts outlined in Section 2 into an applicable framework specific to the research case and questions. This chapter addresses how livelihood strategies are identified (Section 3.1) and how household resilience is assessed (Section 3.2).

3.1. Livelihood diversification

To understand the differences between villages and identify livelihood strategies, as based on the SLF concept and referring to earlier research in smallholder livelihoods and diversification, the variables as shown in Table 3 were investigated (Alvarez et al., 2014, 2018; Kuivanen et al., 2016; Teixeira et al., 2018).

First, demographic characteristics influence choice of livelihood strategies based on age, education but also experience in farming (Kassie et al., 2017; Kimengsi et al., 2019; Quandt, 2018). The highest education of a household member can be influential in choosing more profitable farming strategies and reducing household vulnerability (Bacon et al., 2017). Household size, dependency ratio and hired labour ratio all depict different dimensions of labour availability that can influence farming strategies (Ellis, 2000; Kimengsi et al., 2019; G. Sabastian et al., 2014). A household can be labour constrained despite having many members if the dependency ratio is large (Kassie, 2017; Kassie et al., 2017; Prifti et al., 2019). Hired labour ratio shows the labour input intensity, which is often crucial in smallholder livelihoods (Gollin, 2019a). Second, income sources are included in absolute terms to understand the importance of different sources for households. The major income sources are seasonal crops, perennial crops (incl. non-timber forest products (NTFP) and timber), livestock, fisheries, and off-farm activities. To understand their relative importance, they are included as percentage of total income too. Where households made losses, relative income is set at zero. In addition, income is provided per capita (of adults >14 <65), to balance for different household sizes (Kimengsi et al., 2019). Third, asset levels in terms of operated area and owned livestock (includes shared ownership) give insight into the level of wealth of the household and show a diversification between livestock and cropping income (Ellis, 1998; Kimengsi et al., 2019). Fourth, two set of variables depict intensification and diversification strategies. Income, crop and livestock diversity as measured by the inversed Simpson Diversity Index show how diverse the farming system is. Each of the variables is calculated with a comparison measure, i.e. income share from different sources, crop revenue of different crops and tropical livestock units (TLU) of different animal breeds. Each of these three measures of diversity is reversed as intuitively a higher value depicts higher levels of diversification. Given the prevalence of agroforestry in the area, the estimation of farmers of the share of agroforestry on their land is included. The variable ranges between 0-100%, where 100% signifies a fully implemented agroforestry system on all their land. In addition, the number of seasonal and perennial crops as well as value trees planted across three seasons is included to ascertain where the major difference between farming strategies lie. Both, the diversity indices as well as the count of plants are used in the literature to measure the same concept in a similar way, whereby it is suspected that the diversity index gives a more precise measure as quantity is included as revenue. Also, the inclusion off-farm work and income diversification allows to assess the phenomenon of the persistence of smallholders. Intensification on the other hand shows the intensity of inputs, to capture different intensified farming styles. Smallholders that specialize on highly profitable crops may have higher levels of input in hired labour, seeds fertilizer, and pesticides. Last, access to markets and credits are determinants of livelihood diversification as originally envisaged in the development of the SLF (Ellis, 2000). Smallholders, who are closer to markets, tend to choose more intensive farming strategies and rely on formal and informal credits for their high input systems (Ota et al., 2020).

Table 3: Variables for livelihood strategy identification. Adapted from (Alvarez et al., 2014, 2018; Kuivanen et al., 2016; Teixeira et al., 2018)

Category	Variable	Unit	Description
Demographic characteristics	Household-head age	[years]	Age of household-head may influence farming styles by tradition/innovation preferences and farming experiences
	Household-head education	[years]	Education of household head can influence livelihood strategies by obtained knowledge from school or openness towards learning from community groups or neighbours.
	Household size	[count]	Number of members may influence farming styles due to economic necessities (food provision) or possibilities (more labour force)
	Dependency ratio	[ratio]	Number of household members age <15 and >64 divided by household size. A high dependency ratio can be indicative of a labour constrained household which influences livelihood strategy choice.
	Hired labour ratio	[ratio]	Hours of hired labour divided by total labour input. Corroborates the notion of intensification and, if applicable, labour constraints.
	Highest education in household	[years]	The member with the highest education can influence strategic decisions in farming and add to household income directly or indirectly with remittances.
Income	Household income in shares and absolutes	[%] and [Mio IDR/month]	Mainly relates to income diversification. The diversification of income sources (here: seasonal and perennial cropping, livestock ownership, fisheries, off-farm activities) is one of the key sources to understand livelihoods and applied strategies. Calculations include seasons, mass, market price and plot. Further production cost (seedlings, fertilizer, pesticide, labour).
	Per capita income	[Mio IDR/capita*month]	High per capita income offers the household the opportunity for further investment into farming or alternatively, farm-exit.
Assets	Operated land	[Hectare]	Larger size of operated land may allow farmers to switch to a more extensive type of agriculture with mixed-cropping due to less profitability.
	Livestock ownership	[TLU]	Livestock acts as important source of nutrients and asset for saving which can be used in times of crises. TLU=Tropical Livestock Unit
Diversification	Income diversity Crop diversity Livestock diversity	[1/Simpson]	Calculated with inversed Simpson diversity index $\frac{1}{\lambda} = \frac{1}{\sum_{i=1}^{R} p_i^2}$, where lambda is the index, R is the richness of species (total income, crop revenue in 3 seasons, TLU respectively) and p is the single type compared to R (equals the share) to assess levels of diversification.
	Agroforestry	[percent]	Estimate of the share of land under agroforestry – a common regional agricultural strategy in the study-area
	Seasonal crops Perennial crops Value trees crops Total type of plants	[count]	Assesses crop diversity from the different numbers of plants in three seasons.
Intensification	Input: fertilizer Input: pesticides Input: labour Input: seeds	[Mio IDR/ha*month]	Input intensity indicates intensification strategy
Market and credit access	Market access	[Likert, 1-6=worst]	Market access is a main determinant of livelihood strategies
	Formal and informal credit access	[1=access]	Access to investment capital or safety-nets influence livelihood strategy

3.2. Indicators of livelihood resilience

This section explains the indicators and variables chosen to assess the resilience of livelihoods in the study area (see Tables 4-6)

Using Indicators is a common way to analyse resilience of social-ecological systems (Beccari, 2016; Carpenter et al., 2001; Choptiany et al., 2017; FAO, 2016; Folke et al., 2010; Lisa et al., 2015). They target communities and food systems (Hodbod & Eakin, 2015; Jacobi et al., 2018), households (Ado et al., 2019; Jacobi et al., 2015; Quandt, 2018) and have been used in static agroecological resilience assessments and in agrarian transitions (Blesh & Wittman, 2015; Tittonell, 2020). The chosen variables are largely identical with Quandt's (2018) household livelihood resilience assessment for buffer capacity, and with Jacobi et al.'s (2018) assessment of agroecological food systems for buffer capacity, capacity for learning and adaptation, and capacity for self-organisation. Additionally, each sub-dimension is underlined with empirical work on the region or in humid tropical uplands to justify the use of the respective variable in the indicator. The final choice of indicators was crosschecked with the team of UGM, who supplied regional expertise. A comprehensive step into understanding local resilience is thus provided with the indicator framework presented in Tables 4-6. The indicators combine both objective (e.g., estimation of quantities) and subjective (e.g., ratings and rankings of access to services) measures of household resilience (Jones, 2019; Jones et al., 2018; Jones & Tanner, 2017).

(1) *Buffer capacity* (Table 4) is composed of the classic five livelihood capitals (compare Quandt, 2018) and *farm diversification* which is largely equivalent to diversity of crops and breeds in Jacobi et al. (2018). *Natural capital* centres around common soil problems (Ifejika Speranza et al., 2014), such as erosion and landslide risk (land on slopes), and unfertile soils; problems that are common in the region (Kusumandari & Mitchell, 1997; Labrière et al., 2015; Marfai et al., 2008). In *financial capital*, access to formal and informal credit boost household economy and business opportunity as well as strategic investments and influences coping behaviour (Keil et al., 2007; Lee & Widyaningrum, 2019; Mariyono, 2019b; Mutaqin, 2019). Besides asset-stocks (land, animals and farm equipment), that can be sold to buffer a short-term crisis as a short-term negative coping strategy, *financial capital* includes income diversification, as it smooths consumption during crises (Keil et al., 2007; Niehof, 2004; Schwarze & Zeller, 2005). *Physical capital* describes both asset levels and access to services. Access to markets and road conditions are a crucial determinant of income, labour, and education levels in rural villages (Ota, Herbohn, et al., 2020; Otsuka et al., 2016). Further, irrigation systems are crucial for seasonal cropping in Central Java (Hussain et al., 2006). *Human capital* consists of the standard variables employed in livelihood assessment (M. B. Hahn et al., 2009; Quandt, 2018). *Social capital*, such as community group membership and support in preparation for, during and in recovery from shocks is invaluable (Aldrich, 2015; Guarnacci, 2016; Partelow, 2021). Last, *farming diversity* measures diversification of income, crops and livestock, as well as the implementation of agroforestry, all of which indicate livelihood diversification and a more resilient livelihood overall (Jacobi et al., 2018; Ota, Herbohn, et al., 2020).

(2) *Capacity for learning and adaptation* (Table 5) reflects the adaptation perspective of a resilient system, how systems adjust to better encompass the present or future regime disturbance. The *knowledge of threats and opportunities* includes the respondent's knowledge about shocks that affected his livelihood in the past five years and appropriate coping strategies. Further, access to agricultural extension services and participation in government programmes is an important pathway to raise the anticipatory capacity of farmers and overall performance (Luther et al., 2018; A. Pratiwi & Suzuki, 2017). Farmer field schools have proven

effective in introducing new skills, technology and knowledge into smallholder's live across Indonesia and generally benefit on all five livelihood capitals (Mariyono et al., 2021). Participation in an integrated pest management training was included, due to suspected high pesticide use in the intensely horticulturally used area (Nurbudiati & Wulandari, 2020; Setiawan & Inayati, 2020; Widayati et al., 2017; Yuantari et al., 2015). Next, *reflective and shared learning* included farmers group participation and learning amongst neighbours and between communities. The practice of sharing best-practice farming strategies and participation in agricultural trainings and farmers group increased farm output, sustainability of agricultural practices and resilience (Gultom & Joyce, 2014; Kerr et al., 2016; Luther et al., 2018; A. Pratiwi & Suzuki, 2017; Rustinsyah, 2019). Especially economically disadvantaged community members profit from farmers group participation as they often lack access to information crucially relevant to their livelihood (Yusup et al., 2016). However, farmer group participation can also be attributed to social capital under buffer capacity (Ifejika Speranza, 2013). *Openness to change* is measured by assessing motivations for changes in farming strategies implemented in the last 10 years (e.g. technology and consumer demands, as well as ratings of knowledge gaps and, directly, openness to change. Functioning feedback mechanisms shows the system's ability to provide support for the smallholder (compare Fridayanti & Dharmawan, 2013). It deviates slightly from Jacobi (2018) as it focuses on government subsidies and trainings, social security, as well as community support mechanisms (Luther et al., 2018; Paton & Sagala, 2018; Utami et al., 2018; Warr & Yusuf, 2014). *Existence and use of local and traditional knowledge* are important factors to increase resilience as farming style and livelihoods are adapted to the local bio-climatic conditions (Berkes et al., 2000; Berkes & Folke, 1994; Hosen et al., 2020). This includes soil management strategies, consumption of local staple foods (e.g., cassava and Indonesian corn rice *Nasi Jagung*) and the application of agroforestry (Gliessman et al., 1981; Hobo et al., 2020; Sari et al., 2020; Suryanto et al., 2012; Utami, 2017, Chapter 2). Last, *shared vision* amongst smallholders creates an enabling environment for change towards more sustainable practices and acceleration by learning of best practices (Barrios et al., 2020; Ota, Chazdon, et al., 2020; Rigg, 2006; Rosset & Martínez-Torres, 2012). However, *shared vision* is not included in the calculation of overall livelihood resilience as variables used are redundant to other sub-dimensions.

(3) *Capacity for self-organisation* (Table 6) relates to a transformative element within a household system and to processes of emergence of structure and order within communities that regulate processes and keep system interactions upright. The dimension deviates from Jacobi et al. (2018) as it is translated to the household levels. First, *institutions* relate to the concept of households being able to gain market power by combining their produce and efforts (Mariyono, 2019a). Next, *cooperation and networks* is closely related to *social capital* as it includes reciprocity and trust, which are important in post-disaster recovery (Aldrich, 2012; Utami et al., 2018). Further, it includes as well as savings group participation, an important tool for farmers to pool and accumulate capital for larger investments (Barral, 2018; Danai Manyumwa et al., 2018; Wood et al., 2014). *Self-sufficiency of farming* relates to both decentralization and independence, and local consumption of production; similar to Jacobi et al. (2018). The independence of farmers achieved by income generation of farming and nutritional self-sufficiency or food security is essential for household resilience of smallholders and often provided by home-gardens (Abdoellah et al., 2020; Ansah et al., 2019; Mitchell & Hanstad, 2004; Mohri et al., 2013; Stratton et al., 2020; Suryanto et al., 2012). Last, *political capital* is included as closeness of power to the community or household. The closer power

resides to the community, the more contextualised resilience and climate adaptation ca be (Rosset & Martínez-Torres, 2012; Utami et al., 2018).

Moreover, the calculated resilience is validated with a directly stated subjective measure of household resilience (the ability of the household to withstand a shock, and stated wellbeing (Armitage et al., 2012; Brown & Westaway, 2011; Jones & Tanner, 2017; Quandt, 2018). Further, the obtained resilience scores are compared to coping strategies employed in the past. Access to formal and informal credit is in contradiction to its purpose in buffer capacity conceptualized as negative coping strategy. Whereas buffer capacity includes the ability to make strategic investment decisions, using credits as coping strategy for consumption smoothing has shown can have negative effects for smallholders. Borrowing of financial resources during crises events can lead to *"adverse economic and social consequences* [...] *in rural areas where such* [financial] *markets are poorly developed"* (Pandey & Bhandari, 2009, p. 30). Further, as these markets are usually unregulated evidence shows that interest rate can be as high as 34% on average during crises, which could "*force poor farmers into a perpetual debt trap"* (ibid.). On the other hand, government led and formally organised accessible credit service increases smallholders capacity to recover from shocks without reduction in consumption (Skoufias et al., 2011).

Table 4: Buffer capacity variables. Adapted from Ifejika Speranza, (2013), Ifejika Speranza et al., (2014); Jacobi et al., (2015, 2018), Quandt, (2018).

Indicator	**Variable**	**Unit**	**Description and conceptualized relation to resilience**
Natural capital	Land ownership	[yes/no]	Land ownership is a proxy for wealth. Can be rented or sold in the worst case to sustain livelihood.
	Soil condition	[Likert, 1-6=best]	Likert scale subjective estimation of soil condition: *"I am worried about the future of my farm because of soil related problems."*
	Soil physical condition	[Likert, 1-6=best]	Likert scale subjective estimation of soil condition: *"The soil from my field is easy to plow."*
	Agricultural land on slopes	[percentage]	Percentage of agricultural land of slopes, increases risk of water erosion and landslides. a
	Soil related problems	[count]	Farming problems related to soil (e.g. landslides, erosion, unfertile soils, other); the more problems named the less resilient the system is to shocks.
Financial capital	Access to formal and informal credits	[1=either, 2=both]	Possibility to acquire financial resources either formal (banks) or informal (neighbours, family) raises resilience.
	Livestock	[TLU]	Livestock as measured in tropical livestock units, diversity of animals increases ability to withstand shocks. Can be sold in the worst case to sustain livelihood.
	Size of owned farmland	[ha]	Size of owned farmland in hectare. Larger land area can harbour more diversity of plants that are not susceptible to the same shock. Can be rented or sold in the worst case to sustain livelihood.
	Farm equipment	[count]	Count of all farm equipment (e.g. irrigation machine, sickle, pump, pesticide distributer), which makes
	Income diversification	[1/Simpson]	Diversification of income as measured by the inversed Simpson index based on amount of income of each activity.
Physical capital	Road system connection to infrastructure	[Likert, 1-6=best]	Likert scale subjective estimation of road network quality.
	Road conditions during wet season	[Likert, 1-6=best]	Likert scale subjective estimation of road condition.
	Easy access to irrigation water	[yes/no]	Subjective access to water resource.
	Easy access to household water	[yes/no]	Subjective access to water resource.
	Technical level of irrigation system	[1-4]	Technical level of irrigation system (rainfed, channels and watergates, tubes/concrete canals, sprinkler and tubes).
Human capital	General health of family	[scale 1-10]	Combined values of subjective estimation of each household members health and its ability to practice the livelihood.
	Dependency ratio	[percentage]	Ratio of the population 0-14 and from 65 on to the population between 16 and 64 years of age.
	Education of household head	[years]	Education of household head in years.
Social capital	Community group support	[count]	Support by community group in times of crisis (moral support, donation, labour, financial assistance).
	Community groups – excl. farmers /savings group	[count]	Count of all community groups any member of the household joined excluding farmers and savings group.
	Participation in community groups	[percentage]	Ratio of attended community group meetings out of all group meetings.
Farm diversity	Crop diversity	[count] [1/Simpson]	Crop diversity (across three seasons) is both counted (to include e.g. trees used for animal fodder or as soil bound) and calculated with the inversed Simpson diversity index (based on revenue)
	Livestock diversity	[1/Simpson]	The variety of animals bred is accounted for with the inversed Simpson diversity index based on tropical livestock units
	Agroforestry [Percentage]	[percentage]	Subjective self reported share of mixed cropping/agroforestry.

Table 5: Capacity for learning and adaptation variables. Adapted from Ifejika Speranza, (2013), Ifejika Speranza et al., (2014); Jacobi et al., (2015, 2018), Quandt, (2018).

Indicator	Variable	Unit	Description and conceptualized relation to resilience
Knowledge of threats and opportunities	Extension service access	[yes/no]	Assumes that the extension office informs about potential natural hazard, climatic change or market related threats or opportunities.
	Participation in government program	[yes/no]	Assumes that government programs include information about potential natural hazard, climatic change or market related threats or opportunities.
	Knowledge of an appropriate coping mechanism	[yes/no]	Indicates if the actor is aware of how to respond to shocks and threats.
	Knowledge of a potential shock	[yes/no]	Indicates if the actor is aware of potential shocks and threats.
Reflective and Shared Learning	Received any kind of training recently – excl. gov. or extension service	[yes/no]	Indicates if the farmer has attended any trainings organized by the community or farmer groups. Open answer possible. Trainings, neighbour exchanges and farmer group participation raise exchange of information and best-practices.
	Indicated learning from neighbours	[yes/no]	Farmer groups serve as knowledge exchange basis. Open answer possible.
	Participation in Farmers Group	[percentage]	Ratio of attended community group meetings out of all group meetings.
Openness to change	Openness to technology	[yes/no]	The respondent changed farming practices in the last 10 years by introducing a new technology or answering to
	Openness to consumer demands	[yes/no]	consumer demand.
	Understanding knowledge gap	[Likert, 1-6=	The actor is aware of knowledge gaps: "I need more knowledge in order to be a successful farmer in the future".
	Openness to change	agree]	The actor actively embraces possible change in farming practices: "I am open to changing my farming practices"
Functioning Feedback mechanisms	Received subsidies in the past year	[yes/no]	The respondent received any kind of subsidy in the past year (e.g., cash, rise (Raskin programme), fertilizer, pesticides, seeds or seedlings, farm assets).
	Community group help in times of disaster	[yes/no]	Community groups can provide effective support (moral, cash, in-kind, labour) in crisis.
	IPM participation	[yes/no]	Integrated Pest Management school attendance shows if there are mechanisms regarding the extensive use of pesticides in place.
	Social security/insurance	[yes/no]	Social security can be provided by the district for the poorest, or can be privately acquired and helps the household to overcome idiosyncratic shocks.
Existence and Use of local traditional knowledge	Soil management strategies	[count]	Counting the number of soil management strategies indicates the level the soil is cared for (e.g., soil bounds, intercropping, mulching, terracing/contour farming).
	Applies mixed cropping/agroforestry?	[yes/no]	Mixed cropping/agroforestry is used for generations in the communities, acts as safety net and preserves ecosystem goods and services.
	Weekly meals without rice	[percentage]	Proportion of meals without rice (max three a day or 21 per week/ divided by 21 meals per week. Being less dependent on markets raises the resilience of the household (rice is not grown in the surrounding uplands).
Shared Vision*	Extension service present	[yes/no]	Assumes that the extension office informs about potential natural hazard, climatic change or market related threats or opportunities.
	Participation in government program [yes/no]	[yes/no]	Assumes that government programs include information about potential natural hazard, climatic change or market related threats or opportunities.
	Indicated learning from neighbours [yes/no]	[yes/no]	Indicated learning from neighbours

** The shared vision indicator is described by redundant variables, which are simply interpreted in a different way.*

Table 6: Capacity for self-organisation variables. Adapted from Ifejika Speranza, (2013), Ifejika Speranza et al., (2014); Jacobi et al., (2015, 2018), Quandt, (2018).

Indicator	**Variable**	**Unit**	**Description and conceptualized relation to resilience**
Institutions	Marketing power	[scale, 1-4]	Levels of informal institutions: individually direct to consumer or to traders, direct contract as a farmers group to consumers or to traders (ordered). Highest order reflects highest marketing power and resilience.
	Negotiation of price	[yes/no]	If the farmer can negotiate the price his market power is higher
	Farmers group membership	[yes/no]	Farmers group membership serves as proxy indicator for informal agreements between farmers.
Cooperation & networks	Trust	[Likert, 1-6=full trust]	Trust in borrowing and lending is used as a proxy for trust and tightness of social bonds.
	Savings/Investment group participation	[percentage]	Ratio of attended community group meetings out of all group meetings.
	Reciprocity in goods [ratio]	[percentage]	Ratio receive to give monthly. Reciprocity reflects bonding social capital.
	Reciprocity in currency [ratio]	[percentage]	Ratio borrow to lend yearly.
Self-sufficiency of farming	Self-sufficiency (food)	[percentage]	Yearly estimate of self-consumption of production tries to answer how self-sufficient the farm is.
	Self-sufficiency (farm income)	[Likert, 1-6=full support of livelihood]	Estimation of income sufficiency tries to state how independent the household is.
	Home garden size	[m^2]	
Political capital	Political power: Neighbours/friends/relatives Community leaders Community groups	[rating, 1-6=best]	Closeness of political power to the community is explained via decision making power in actors close to the household as opposed to actors further away to the household (e.g. government officials, village office). Can be also explained

4. Methods

This chapter provides an overview on research design (Section 4.1.), study sites and sampling (Section 4.2.), followed by a description of the four phases of data collection (Section 4.3.) and a description of the data analysis (Section 4.4.).

4.1. Research design

The research followed a deductive, cross-sectional and comparative case study approach in a sequential mixed-method design to ascertain the difference in livelihoods between the two villages from primary data (Yin, 2017). As to the types of cases chosen, Leksana can be referred to as the critical case in relation to Penanggungan and the three guiding hypotheses, which are to be investigated (Matthews & Ross, 2010, p. 128). However, as both villages are suspected to exhibit regionally prevalent, albeit different livelihoods, both can be argued to be representative or typical cases for their respective strategies (ibid.). In livelihood typology construction, a cross-case comparison approach was used to identify prevalent livelihood strategies and consecutively measure their resilience across both villages. Both, comparative and cross-case case analyses are based on the cross-sectional data collected during fieldwork from July to October 2018.

Essentially the research is exploratory and descriptive regarding the description of livelihoods in the respective villages and the identification of strategies. A small explanatory component is introduced by ascertaining the main motivation to take up different strategies. The resilience assessment has an evaluative nature as it indicates the capabilities of households to anticipate, withstand, adapt and transform in relation to prospective system perturbations (Matthews & Ross, 2010). The overall research design therefore forms a highly reliable and internally valid picture of the sample. Only limited external validity or generalisability of the livelihood strategies in a regional context is given, which is even less for the highly contextually defined resilience assessment.

The triangulation of qualitative and quantitative data was intended to move the research paradigm from positivist towards a more constructivist and culturally informed perspective on livelihoods (ibid.). However, given the scope of the thesis, analysis of qualitative data was excluded, and the prevailing research paradigm was therefore positivist (ibid.). Thus, the results are limited from an interpretivist perspective as well as from critical historical perspectives that would potentially be able to uncover causes for inequality and differences between the villages.

Finally, positionality had to be considered; a topic usually neglected in quantitative research (Jafar, 2018). The researcher in the present case was white, near thirty, male, born in Central Europe and had previously no contact to South-East Asian, Indonesian, or Javanese culture. As this could have potentially led to cultural bias in interpretation, all elements of the research design were crosschecked with the local support team for Universitas Gadjah Mada Yogyakarta, the research protocol was constructed after a local trial, and frequent input on local cultures from the team of supervisors and translators was integrated.

4.2. Study sites and sampling

At the Sustainability Transitions Summer School for Food Security and Climate Change 2017 (STSS-FSCC-2017) organised by Universitas Gadjah Mada (UGM), Yogyakarta and joined by several universities of South East Asia and BOKU, an initial inquiry into farming systems, soil conditions and socioeconomic characteristics of household in the two hamlets was conducted. The research revealed a stark difference between the two communities in regard to their farming practices and socio-economic conditions (UGM, 2017). A joint research team of BOKU and UGM selected the two study sites for further research to reveal causal mechanisms for their differences. The research was conducted in the two hamlets of Wanasari/Tamansari (village of Leksana, district of Karangkobar) and Penanggungan II (village of Penanggungan, district of Wanayasa) in Banjarnegara regency/district in Central Java (Jawa Tengah), Indonesia. Note that the adjacent hamlets "Tamansari/Wanasari" are reported as "Leksana" and the hamlet of Penanggungan II as "Penanggungan" for simplification.

Banjarnegara regency lies partly in the hilly highlands of Central Java, Indonesia and spans an area of approximately 1000 km^2. With a population of about 1 million, agriculture constitutes one of the main economic activities with about 40% of GDP. On average smallholder farm size is about 0.5-1 ha (Griffin, 2020; Rigg & Salamanca, 2017). Typical crops are maize, cassava, potato, and cabbage. The regency comprises 20 subdistricts. Some of those subdistricts such as Karangkobar and Wanyasa are in the mountainous highlands of Java with slopes of up to 40% gradient and precipitation of about 4120 mm (UGM, 2017). The monsoon rains generally last from October to April, being subject to increased variations and the occurrence of more extreme events, suspected to be caused by climate change. Due to the topographical and meteorological conditions the area suffers increasingly from soil erosion and landslides. In two neighbouring districts, namely Karangkobar and Wanayasa a different agricultural and societal development can be observed. Two distinct agricultural management systems have evolved in the typically local villages of Leksana and Penanggungan which are suspected to centre around farming of potato and a more diversified crop-livestock-agroforestry system. In both areas, the observed distinct livelihood strategies were subject to research. In general, both livelihoods seemed to be strongly impacted by market access, land degradation and climate change. The diversification of livelihoods and their resilience is the main interest of this study. Figure 3 shows the location of the study-areas and Table 7 provides a detailed description.

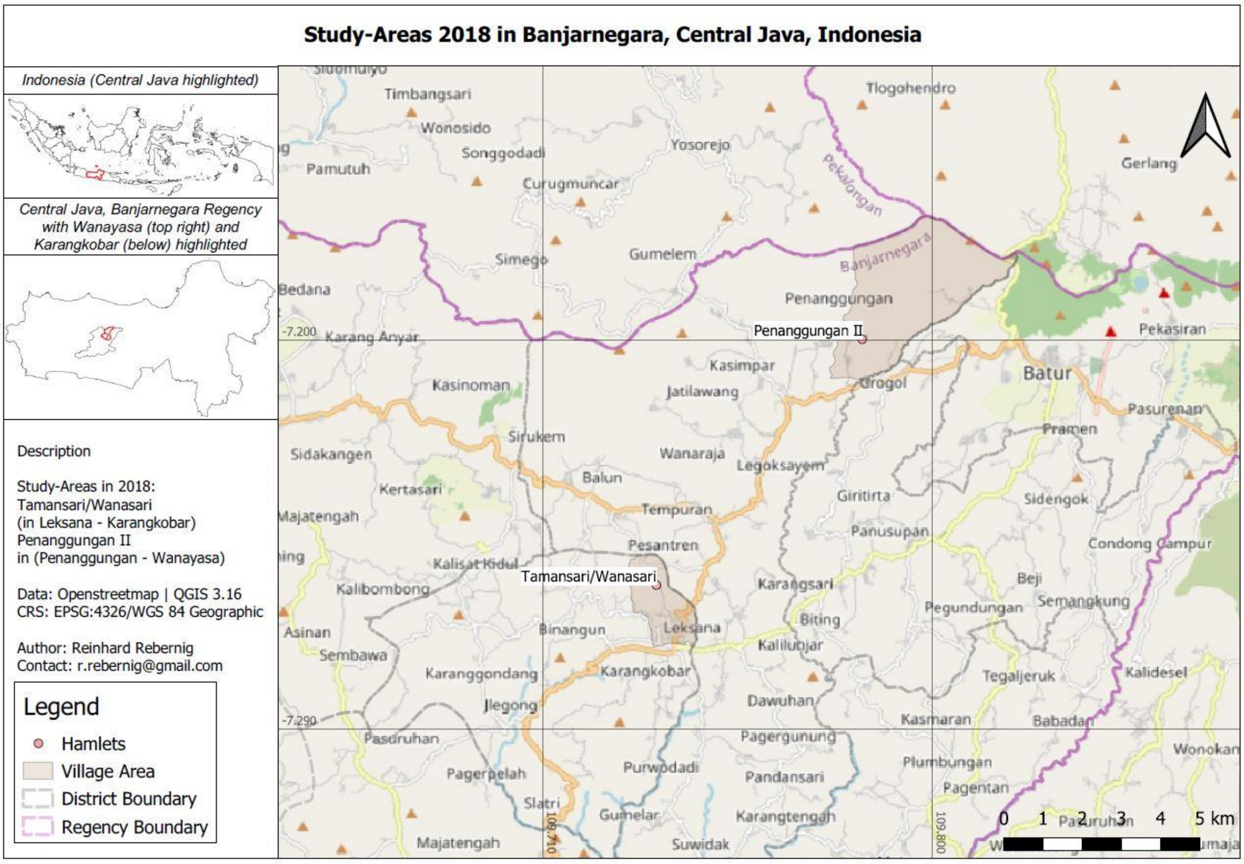

Figure 3: Study-Areas in Banjarnegara, Central Java, Indonesia (2018). Own illustration.

Table 7: Description of study-areas. Compare Sari et al., (2020); Hobo et al., (2020), UGM, (2017).

Village	**Leksana**	**Penanggungan**
Hamlet	Tamansari/Wanasari	Penanggungan II
District	Karangkobar	Wanayasa
Regency, Province	Banjarnegara, Central Java	
Altitude	Between 1200-1400 MASL	
Precipitation	Up to 4120 mm/year	
Slopes	Slight to mostly steep (40%)	
Dominant farming strategy	Agroforestry, horticulture, crop-livestock systems	Horticulture
Agroforestry	71%	3%
Privately owned land	96%	69%
Livelihood strategy	Diversified	Intensified and specialized
Major crops	Cabbage, mustard greens, chilli, maize, coffee, trees for fruits, timber and forage feed	Potato, carrot, cabbage
Input (Pesticides, Fertilizer)	Mid to high	Very high
Livestock	Common (self-owned and shared ownership)	Infrequent
Soil fertility management and soil and water conservation	Common: terracing, mixed-intercropping, mulching, multi-cropping, soil bounds, ridge techniques, agroforestry	Common: terracing, intercropping, crop rotation; infrequent: others
Market access (road connection)	Good (recently)	Very good
School	None	Primary school
Access to agricultural extension service	Frequently	Infrequent / Unclear
Workshops with PT. Indonesia Power	Yes	No

4.3. Data collection

The EU funded[3] project was organized and implemented in collaboration with UGM, Yogyakarta and encompassed the research of four BOKU students with different dissertation-topics (soil health and pesticide residues, soil carbon and farm transitions, farm inheritance and social change, livelihood diversification and resilience). Two research teams collected data from the same sample. While the UGM team collected household economic data, the second team consisted of the four BOKU students who collected data according to their dissertation topics. Simple random sampling method with the Slovin formula was employed to ascertain a minimum sample size of 73 households from total 265 families of both villages. Next, proportionate random sampling determined that at least 44 households in Leksana (160 families) and 29 households in Penanggungan (105 families) should be interviewed. Last, village heads of both villages were asked to recount 45 random household names from their memory. If a team could not detect the household head or similar in two consecutive visits, the next best household down the road was chosen. The sampling methodology and sample was congruent with the study of Sari et al., (2020). Figure 4 gives an overview on the different fieldwork phases between July and October 2018.

The BOKU research team was supported by forestry and agricultural-economics students at Universitas Gadjah Mada (UGM), Yogyakarta acting as translators. Prior to the interviews, the translators were instructed into the aim of the master theses and the common survey-protocol was tested in the region of Gunungkidul, Yogyakarta and adapted. The area was chosen for geographical accessibility and comparability of agricultural systems (apart from the cultivation of rice) and is already part of ongoing research projects of Universitas Gadjah Mada (Hobo et al., 2020; Sari et al., 2020; UGM, 2017). This, as well as the desk research, helped inform the survey questions and the livelihood indicators necessary for the household livelihood resilience assessment.

[3] This project has been funded with support from the European Commission under Call EAC/A04/2015. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Time-span:	End of July	August		Early October
	Phase I	Phase II	Phase III	Phase III
Objective	To introduce oneself to the community and gain in-depth understanding of the local context and the history of the community	To gather key-information on livelihood diversification and resilience	To aquire extensive insights into motivation of farmers, perspectives of village officials and extension officers, visons of company representatives	To exit the community meaningfully; validate preliminary findings and understand aspirations and future plans of farmers
Methods	1. One focus group discussion per village 2. Key informant Interviews	1. Household Survey 2. Economic data survey	In-depth semi-structured interviews	One focus group discussion per village
Sample Size	1. n=15-20 Leksana / 20-25 Penanggungan 2. n=1 L / 1 P	1. n=40 L / 40 P 2. n=45 L / 45 P	n=20 (10 L /10 P)	n=20-25 L /25-30 P
Sampling	1. Random Sampling 2. Purposive sampling	1. Random sampling 2. Random sampling (same respondents)	Purposve sampling: Village officials, community group leaders, company representatives extension officers, farmers of both gender	Random sampling

Figure 4: Fieldwork process (July - October 2018)

The aim of the initial research phase was to familiarize the research team with the two communities and to gain better understanding of the historical development trajectories of farming practices. In each community, several (undocumented) transect walks, key informant interviews, and a focus group discussion were conducted (Penanggungan: Pictures 1-3; Leksana: Pictures 4-6). The data collected helped the research team to understand better the current conditions, existing path-dependencies and if and why in the two communities two distinct agricultural management practices predominate. Further, the gathered data fed into the design of the quantitative interview protocol.

The goal of phase two was to gather quantitative household and farm data. The survey was split into two survey protocols, with one focusing on farm economics (n=80) and the other (n=80) on livelihood diversification and household resilience. An additional third focused on soil sampling for pesticide residue analysis, which is not considered in the present dissertation. Overall, 78 observations were congruent between the two survey protocols.

Phase three consisted of a total of 24 semi-structured in-depth-interviews inquiring further into the livelihood strategies. Nine farmers in Leksana were interviewed including the village head. Additionally, a village secretary, representatives of the agricultural extension service and a representative of PT. Indonesia Power, an associated company investing in farming transitions villages upland of Merawu watershed were interviewed. Further nine farmers of Penanggungan and the village secretary were interviewed. The interviews aimed at identifying rationales and motivations for the suspected difference in farming practices, as well as uncovering gender differentials, risk transfer mechanisms in the community, the role of the local coffee project implemented by PT. Indonesia Power and the connection between access to financial services, farmer group activities and the support of agricultural extension officers.

The final phase of the research constituted an FGD aiming at validating gathered data. After preliminary data analysis and in-depth-interview, a FGD in each community was held. It focused on verifying the key findings for each of the four master thesis topics.

The final data set intended for the present dissertation comprised two initial and two validating focus group discussions, 78 farm-economic surveys congruent with 78 household surveys that were sectioned into four dissertation-specific segments. The survey protocol for the latter is attached in appendix A. Further 20 qualitative semi-structured interviews specifically on livelihood diversification and household resilience were conducted. They followed a semi-structured topical guide and were on average of 1-1.5 hours length, which included satisfied ethical considerations by approval of the household head. For the focus group discussions and semi-structured interviews, the methods of rapid rural appraisal with participatory elements were used. Both were not analysed for the present thesis due to the volume of data and complexity of the research problem.

Picture 1: Panorama of Penanggungan. Photo: Author

Picture 3: Crop failure in Penanggungan. Photo: Author

Picture 2: Potato fields in Penanggungan. Photo: Author

Picture 4: Panorama of Leksana. Photo: Author

Picture 5: Fields in Leksana. Photo: Author

Picture 6: Mixed cropping in Leksana. Photo: Author

4.4. Data analysis

This section describes how the methodological approach of the thesis is implemented. First bi-variate testing methodology is reviewed, which is applied throughout the dissertation to ascertain differences between two independent groups. A special attention to robust testing methodology is given due to the small sample size and mostly skewed distributions. Next, decision tree methodology is explicated which is used to identify livelihood strategies. SPSS 26 was employed for the decision tree analysis due to the favourable graphical interface and output (IBM Corp., 2019). Last, composite asset indicator methodology literature is reviewed in parallel to outlining consecutive steps of indicator building. Limitations are reviewed at the respective methodological step.

Small samples pose considerable challenges for hypothesis testing that stem from their distribution and variance. While many authors in literature resort to justify the use of parametric methods with the *Central Limit Theorem* (CLT) (the approximation of a sample n>30 to a normal distribution), for correct correlation and inference variables still must be tried for necessary assumptions before choosing the appropriate test (Castro Sotos et al., 2007; Sawilowsky, 2011). Apart from the decision tree analysis, all tests were performed in Stata 16 (StataCorp, 2019).

4.4.1. Bi-variate testing for differences between independent groups

Bivariate correlation can be assessed with Pearson's r correlation coefficient, or Spearman's ρ and Kendall's τ rank correlation coefficients to ascertain the relation between two continuous random variables (Chen et al., 2002). Pearson's r is the usual choice as it can provide a comprehensive description of the association of two continuous random variables that have a linear association. It assumes bivariate normality, homoscedasticity, finite variances and finite covariances, and is thus very sensitive to outliers. Spearman's ρ or Kendall's τ both apply to ranks, and thus provide a measure of monotonic relationships between two continuous or ordinal random variables. Because of the ranking procedure applied both methods are considered robust to outliers, suitable for skewed data and do not have distributional assumptions (Newson, 2002). However, Kendall's τ is considered as "*more robust and slightly more efficient than Spearman's rank correlation, making it the preferable estimator from both perspectives*" (Croux & Dehon, 2010, p. 509; Kitagawa et al., 2018).

The non-parametric Kendall's test τ measures the monotonous association (or strength of dependence) between two variables by comparing concordant and discordant ranked observations. Monotonous association varies between perfect dependence of $\tau = \pm 1$. Dependence is a more general relationship between two variables (which does not necessarily include correlation) than correlation, however, if variables are independent from each other, no correlation exists. This partially explains why Kendall's τ reports generally lower levels of association than the effect sizes of the other two correlation coefficients. As most of the variables were skewed, Kendall's τ_b was considered the appropriate measure as it corrects for tied ranks if necessary (ibid.). In case of binary variables, the coefficient is similar to Pearson's ϕ and therefore appropriate. The test was applied with $H_0\colon The\ variables\ are\ independent$ and $H_a\colon The\ variables\ are\ not\ independent$. Since the literature is very sparse on advice for thresholds, $\tau_b > 0.5$ at the critical value of $\alpha = 0.01$ is considered as strong association, in which case the H_0 is rejected.

The overall sample size was more than twice as large as necessary to assume the CLT (78 households), which would in principle allow to use z-tests that rely on population parameters. Population parameters were unknown, and sub-samples are relatively small and contain many outliers. Thus, Students' T-test of equality of means (hereafter T-test) was the preferred method, if the assumptions of i) independent and identically distributed observations, ii) normal-distribution, iii) equal variances, and iv) no significant outliers exist, were satisfied. In case of binary dependent variables (binomial distribution) a two-sample proportion test was conducted. Otherwise, robust methods were considered.

Generally, the sample consisted of independent and identically distributed observations, given the random sampling procedure and households as unit of analysis. First, the distribution of the considered variable was tested for normality with the Shapiro-Wilk test (suitable for samples 4 ≤ n ≤ 2000) under the $H_0\text{:}\,The\ variable\ follows\ a\ normal\ distribution$, and $H_a\text{:}\,The\ variable\ does\ not\ follow\ a\ normal\ distribution$, with the significance criterion at $\alpha = 0.1$. Second, if the variable followed a normal distribution, Levene's test was employed next. The null hypothesis for equality of variances $H_0\text{:}\,variance_0 = variance_1$ ($H_a\text{:}\,variance_0 \neq variance_1$) was tested at $\alpha = 0.1$ at the mean of the distribution, and with Brown and Forsythe's extension at the median and the 10% trimmed mean, guaranteeing robust results. The higher threshold of $\alpha = 0.1$ was chosen due to sample size and application of all three test versions. Third, if the variable was normally distributed a T-test tested the two tailed $H_0\text{:}\,mean_0 = mean_1$ ($H_a\text{:}\,mean_0 \neq mean_1$) on all conventional significance levels (and CI=95%). In case the variable followed a normal distribution but had unequal variances the test was adjusted with Welch's approximation (Delacre et al., 2017).

4.4.2. Robust tests for non-parametric distributions

In case the assumptions were not fulfilled robust methods were considered, e.g., Mood's median test (hereafter median-test), Wilcoxon / Mann-Whitney U test (hereafter ranksum), or, more appropriately, quantile regression at median location and the Hodges-Lehman median difference. Now, opposed to frequent misuse in literature, the first two non-parametric methods above are simply not direct equivalents for parametric methods (Conroy, 2012).

The median-test investigates for example "*a likely consequence of drawing two samples from populations with equal medians: that a similar proportion of observations in each group will be above and below the grand median of the data*" (Conroy, 2012, p. 187), which is not the same as a substitution of the means with medians in the H_0 of the T-test and the comparison of two sample-medians with each other. The possible rejection of the H_0 is not an answer to the question of *how* the distribution between two groups differs, and the median-test is therefore best combined with a visual check of box-and-whisker plots. Given the quantity of variables tested, the method was not employed.

Similarly, ranksum tests for equality of medians only under the strong assumptions of either symmetrical distributions about the sub-group medians, or that asymmetric sample-distributions have the same shape. Additionally, homogeneity of variances is assumed, which - if not fulfilled - inflates Type I error rate of false positives in skewed datasets (Kasuya, 2001; Zimmerman, 2004). Contrary to popular opinion, the dependent variable does not need to be ordinal but can be continuous (Sawilowsky, 2011). Wilcoxon developed the test originally for stochastic dominance (Conroy, 2012). Generally, the ranksum-test examines the difference in distributions based on mean ranks with the $H_0\text{:}\,The\ distributions\ of\ the\ two\ groups\ are\ equal$, or more precisely, that there is a 50% probability that a randomly selected observation from one sample exceeds a randomly selected observation from the comparison sample. This H_0 is essentially the formulation of stochastic equality, where the cumulative distributive functions of the sub-groups do not cross in the population (Emerson, 2011). While the test is considered robust to outliers, the ranking procedure obviously diminishes the difference between observations drastically and the test result can only be indicative about the distribution. The test can be used with $n \geq 7$ and the z-statistic is reported because the standardized Wilcoxon statistic asymptotically follows a standard normal distribution (Neuhäuser, 2011). The P value in turn corresponds to the chance of random sampling resulting in having mean ranks as being as far apart as in chosen sub-group experiment (Sheskin, 2007). In Stata 16, the ranksum-test reports statistical significance for two test statistics. First, the test statistic of Mann-Whitney *U* describes, by looking at all possible pairs (here the product of 40 observations in Leksana and 38 observations in Penanggungan equal 1520 pairs), the number of times observations in one sample precede observations in the other sample in the ranking. The reason why sometimes half pairs are reported lies in that the algorithm assumes tied ranks for half its calculations. (Conroy, 2012). Next, the command reports $P(X > Z)$ or the effect size of the probability or likelihood of an observation of a group having a true value higher than an observation in the comparison group, which is a useful measure of stochastic dominance (ibid.).[4] The choice of alternative hypothesis is then determined by the realization of the above assumptions. If the assumption of equality of variances is fulfilled the appropriate $H_{a_1}: The\ distributions\ of\ the\ two\ groups\ are\ not\ equal$ is applicable. If the variances are not equal interpretation between groups becomes challenging and the $H_{a_2}: The\ mean\ rank\ of\ the\ two\ groups\ is\ not\ equal$ is applicable. Only in the rare case when all assumptions hold (symmetrical distribution or same shape in different location, homogeneity of variance) the alternative hypothesis can be properly described as $H_{a_3}: The\ medians\ of\ the\ two\ groups\ are\ not\ equal$ (Divine et al., 2017).

The assumptions for ranksum-test can be assessed with the Levene test and Kolmogorov-Smirnov equality-of-distributions test (hereafter Ksmirnov; $H_0: Samples\ have\ equal\ distribution$, $H_a: Samples\ have\ unequal\ distribution$[5], tested at $alpha = 0.1$) or graphing of histograms and kernel-density to assess similarity in shape. However, the assumptions are rarely fulfilled. In conclusion, both the Mann-Whitney U statistic and the effect size for stochastic dominance is in either case a useful measure to get an impression on how the data of two sub-groups differ even if assumptions are not met. Thus, the present dissertation tests for differences in distributions with ranksum tests, under $H_{a_2}: The\ mean\ ranks\ of\ two\ groups\ are\ different$ where the test makes no assumptions about the sub-samples. The reported effect sizes of the ranksum-test give a more complete picture about differences in sub-group distributions as compared to the median-test, which is therefore considered redundant and not considered for analysis.

To then ascertain differences in medians quantile regression at median location was employed (Davino et al., 2014; Koenker, 2017). The model is robust to outliers and holds in principle no assumptions about homoscedastic residuals (Conroy, 2012; Waldmann, 2018). However, the standard error appears to be underestimated when residuals do not follow an independent and identical distribution and thus affect point estimates (Rogers, 1993; Wenz, 2019). As the sample size was small, non-parametric bootstrapping was considered but omitted, as most of the variables' distributions were skewed, some leptokurtic and

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[4] In other words, it can be understood as a pairing of each value of two groups and dividing the count of number of times where the first group is larger than the second by the total number of pairs.

[5] While Ksmirnov tests essentially the same hypothesis as the ranksum-test it relies on differences in the cumulative distribution of the compared groups, whereas ranksum compares mean ranks. The Ksmirnov test is therefore very sensitive to large absolute differences in shape, spread and median. For testing differences in medians with ranksum it can be used to check the assumption of equal distributions. However, ranksum is geared towards *consistently* (not by magnitude) larger values and provides interesting statistics about stochastic dominance in comparing sub-groups in addition to the information if the distributions are not equal.

others had heavy tails. Instead, an analytical estimator for heteroskedasticity-robust standard errors was used (Machado et al., 2011; Machado & Silva, 2013).

To test for equality of medians with the $H_0: median_A = median_B$ and $H_a: median_A \neq median_B$ at all conventional significance levels the model is specified with Equation 1 equation:

$$Q_\tau(y_i) = \beta_0(\tau) + \beta_1(\tau)Group_i + \epsilon,$$

(Equation 1: Regression model at median location)

where y_i is the dependent variable, which is explained at sample median latency τ_y by the constant β_0 (median of comparison group $Group_0$), the difference in medians β_1 to the other group $Group_1$ and the error term ϵ. Congruently to linear regression which tries to minimize the mean square error, quantile regression minimizes the median square error. Essentially, the coefficients become functions dependent on the quantile.

Note that, while quantile regression tests for difference in medians, it only explicates the median difference between individuals of two groups if the distributions are symmetric with equal variances (Newson, 2002, 2006). For this the Hodges-Lehman median difference is usually employed which coincides with the median difference between the groups (obtained from quantile regression) if the distributions are symmetric (Conroy, 2012; Hershberger, 2011; Rosenkranz, 2010).

In conclusion, in the event that the variable of interest follows a non-normal distribution, ranksum will test for equality of distribution and provide the useful measure of stochastic dominance. Consecutively, the differences in medians between the two groups are obtained with quantile regression at median latency.

4.4.3. Identification of livelihood strategies using decision trees

Preliminary data analysis showed that in both villages, farmers with and without agroforestry or conventional strategy, as well as animal husbandry and fishery were present. For determination of livelihood strategies, the Exhaustive Chi-squared Automatic Interaction Detection (CHAID) Decision Tree model in SPSS 26 was employed (IBM Corp., 2019). As RQ1-SQ1 seeks to understand differences of livelihood strategies between the villages, the village was the dependent variable. A total of 33 independent variables, both continuous and nominal at household level were considered.

Usually, methods chosen to develop farm typologies are Principle Component Analysis (PCA) and a consequent clustering method (e.g. hierarchical Ward's or PAM) (compare Kuivanen et al., 2016). These methods were not considered due the majority of the variables follow a non-normal, leptokurtic and skewed distribution with many empirically justifiable outliers. Further sampling adequacy was not given, as the cases-to-variables ratio was between (2.36-2.689) and did not meet any of the criteria listed in OECD (2008, p. 66). However, the CHAID algorithm has been frequently used in development studies with a socio-ecological context for classification purposes and climate risk, vulnerability and food security analysis (Agula et al., 2019; Diedrich et al., 2017; Faradiba & ZET, 2020; Lokosang, 2015; Ondiek et al., 2020; Senganimalunje et al., 2020; Yohannes & Webb, 1999).

Classification trees distribute a basic population into partial populations or segments by using predicting variables. The decision tree shows, which predictors have more influence on the dependent variable. The created partial populations are ranked according to the strength of the influence of the dependent variables. The CHAID Decision Tree is the most commonly building method for classification purposes in various disciplines, such as medicine, economics and psychology (Ritschard, 2013). CHAID discovers automatically relations between independent variables on the basis of Chi-squared tests. As CHAID is non-binary it leads to bigger decision trees. CHAID determines in each analytical step the predictor, which has the highest influence on the category of the independent variables. The *exhaustive* method uses a more precise method as it calculates every possible distribution for each predictor variable (Bühl, 2019, p. 677). For both dependent and independent variables, the scale of measurement is of no importance. If the scale is continuous the variable values are binned into categories, which in case of outliers has shown to deliver more robust results than winsorization (Nyitrai & Virág, 2019). If the categories of independent variables do not significantly differ from each other in their relation to the dependent variables they are pooled.

Due to the small sample size and after much experimentation, sizes of parent and child nodes were set at 10 and 5 respectively, with a maximum tree depth of 3 to guarantee meaningful outcomes. The model specification included the conventional significance threshold of $\alpha = 0.05$ with Bonferroni adjusted significance levels. Cross-validation (10-fold) was employed for robustness. Split sample partitioning and validation was not considered due to the small sample size.

Two measures were employed to understand farming efficiency and respective livelihood outcomes. First the benefit-cost ratio (BCR) was calculated as the ratio between the sum of revenues and sum of costs. This measure was applied to seasonal crops and seasonal and perennial crops combined.[6] Next, as measure for profitability the gross crop margin was calculated by the difference of revenues and costs divided by a measure of capital which in this case is the operated land area.

4.5. Composite indicator methodology

Following the literature review the three dimensions of resilience and the overall agroecological indicator was constructed. An additive composite asset index was created. The computation of the composite indices was based on the guidelines of the OECD and JRC (2008), and inspired by Hahn et al. (2009) and Quandt (2018). This approach is commonly used in development research and in a multitude of policy areas such as the UNDP Human Development Index, the UNDP Global Multidimensional Poverty Index, the Environmental Performance Index, the IPCC-Livelihood Vulnerability Index, or the Gender Empowerment Index (OECD & JRC, 2008). Composite asset indicator construction in livelihood vulnerability and resilience literature has in the past been heavily criticized for being a black-box, which suffers from compensability and non-comparability. A black box that, while just sufficing to identify the presence of a concept or specific level of a group, is in principle unsuitable for policy evaluation (Hinkel, 2011). Therefore, each subsection contains a discussion of limitations in the methods chosen for indicator construction.

First, the variables of each sub-component were checked for normality and screened for outliers and anomalies to avoid distortion during the transformation. Outliers were kept if empirically justifiable and anomalies were removed. Imputation and winsorization was avoided, due to the small sample size.

[6] Perennial crops, such as value trees, profit from input over several years. Often input that is applied to seasonal crops is applied to perennial crops as well. While this previous input is not included, the combination of seasonal and perennial crops corrects for windfall profits from harvesting value trees.

4.5.1. Bivariate analysis of collinearity and multivariate analysis of conceptual reliability

Next the considered variables were investigated with bi- and multi-variate method, as recommended by the OECD guidelines. All variables within each sub-dimension were assessed for their pairwise-correlations with robust rank correlation of Kendall's τ_b and Spearman's ρ to avoid emphasising one aspect of resilience. If the variables crossed the threshold defined in Section above, they were excluded. Walker (2003) provides a guide on how to translate between the three correlation coefficients, but results were directly confirmed with Spearman's rank correlation ($\rho > 0.7 = strong\ correlation, p < 0.01$) (G. Smith, 2015). Measures of association from Kendall's τ_b are reported in Appendix B, Tables B 1-16. Spearman and Kendall are provided due to association values rarely crossing the defined thresholds. The restricted index thus avoids overrepresentation of collinear variables which is a prerequisite for additive indices (Gan et al., 2017).

Further, the OECD guideline recommends assessment of multivariate collinearity and conceptual reliability with Cronbach's coefficient alpha, which has been extensively used in livelihoods, vulnerability and resilience indicators to assess the latent concept of an indicator present in the underlying variables (Beccari, 2016; Cutter et al., 2014). It is in principle the average correlation among all possible pairwise combinations of a group of variables, i.e., their intra-correlation (Cronbach, 1951). Cronbach's coefficient alpha was originally intended to assess the reliability of Likert scale survey items in psychometric measurements where a value of alpha greater than 0.7 is expected and a value greater than 0.9 is recommended. However, assessing the dynamics of reliability and internal consistency of a latent construct with Cronbach's coefficient alpha is disputed in the root discipline of the coefficient (Peters, 2018). In other social sciences disciplines, differences of scale in the variables considered to indicate a concept essentially bias the reliability measure (Ursachi et al., 2015).

Cronbach's coefficient alpha has very strict assumptions. The measured concept must be unidimensional with uncorrelated errors and essential tau-equivalence between variables, i.e., identical co-variances (Tavakol & Dennick, 2011). Violating the assumptions is certain when using a multitude of variables that are measured on binary, nominal ordinal, and continuous scales. The distribution of the re-scaled or standardized variable leads to bias as demonstrated by Sheng & Sheng (2012), which is disputed (Woodruff & Wu, 2012). Trizano-Hermosilla & Alvarado (2016) and Starkweather (2012) both review literature on shortcomings of and alternatives to alpha. Cronbach's Coefficient alpha is not considered to be a modern estimator for conceptual reliability (Dunn et al., 2014; Starkweather, 2012). Further, Cronbach's coefficient alpha is unsuitable to assess dimensionality of composite asset indicators, where factor or cluster analysis yields more fitting information. As best recent alternative to Cronbach's coefficient alpha, McDonald's omega, a confirmatory factor analysis model, has been proposed as alternative which does not require essential tau equivalence and allows for different factor loadings (Brunner et al., 2012; Dunn et al., 2014; McNeish, 2018). The coefficient is bound between 0 (the concept is not reliable) and 1 (full reliability). In the present dissertation the coefficient is calculated after re-scaling and the threshold of 0.5 for construct validity is adopted, which Cutter et al. (2014) apply in their innovative study of resilience in US-American counties. Generally, the indicator is not expected to be externally valid due to compensability between variables and the highly contextual nature of the variable selection.

4.5.2. Normalization of individual variables

Second, the proportion of maximum scoring (POMS) method (or min-max transformation method) was chosen as normalization method as it allows for comparison of different measurement units (binary, nominal ordinal and continuous) (Smith, 2015). Talukder et al. (2017) agree in their overview on the effect of normalization and aggregation techniques for CAIs in agricultural sustainability assessment on the shortcomings of this method regarding outliers and the preservation of unequal variances in the re-scaled variable. However, given that most variables were distributed highly leptokurtic and skewed with left tails, POMS is the preferred method as it is fit for variables within a close range (Veljko et al., 2016). Alternatively, z-score standardization via mean and standard deviation, or distribution robust measures of median and inter-quartile range or median absolute deviation can be used for standardization if the relative distance of outliers should be maintained (Kappal, 2019). Thus, the survey results for each of the sub-components were converted to scale of 0 to 1 (OECD & JRC, 2008), where 1 is to represent the response indicating highest level of resilience, and 0 is to represent the response indicating the least level of resilience. Ordinal data types stemming from questions with multiple answer choices (typically Likert scale) were assigned values with equal distances within the range of 0 to 1. Binary response variables were not transformed, whilst acknowledging their strong influence on the composite indicator. In general, a range [0,1] allows the sub-components to be averaged into the composite indicators following the assumption that higher scores indicate higher levels of livelihood assets and greater livelihood resilience. All variables were re-scaled across all households to make them comparable with equations

$$norm_{var_{qi}} = (q_i - \mathrm{q_i}_{min})/(q_{i_{max}} - \mathrm{q_i}_{min})$$

(Equation 2: Proportion maximum scoring method)

, where *i* is the respective variable of household q and their respective minimum and maximum values in the sample. The rescaled variable is inversed if the relationship with resilience is conceptually opposite (Adu et al., 2018; M. B. Hahn et al., 2009; Utami et al., 2015).

4.5.3. Weighting and aggregation

Third the indicator is aggregated by using linear combination of naturally weighted arithmetic means. Although this sensitive step in the process possibly distorts the outcome the applied method is considered robust if the underlying concept is consistent (Dobbie & Dail, 2013; Greco et al., 2019; Mishra, 2008). Further, the arithmetic mean has the advantage that it is easy to understand, as for example the geometric mean (Fritzsche et al., 2014; GIZ & EURAC, 2017). However, the method assumes perfect substitutability with constant trade-offs between indicators and preference independence, where an additive function exists only if the indicators are mutually preferentially independent (Angeon & Bates, 2015; Bates et al., 2014; Greco et al., 2019; OECD & JRC, 2008; Rogge, 2018). This condition is widely disregarded in empirical literature of composite indices as it is in general difficult to fulfil (ibid.). Last, compensability between indicators remains a problem that cannot be avoided. Thus, indicators are aggregated at sub-dimensions, dimensions and overall resilience separately and individual variables are investigated. After the survey results for each question and respondent are converted to fit a scale of 0 to 1, the sub-dimensions of each resilience dimension are aggregated with

$$subdimension_{sq} = \left(\sum_{i=1}^{n} normvar_{iq}\right)/\mathrm{n}$$

(Equation 3: Aggregation of variables into sub-components)

Fourth, the composite asset index is calculated for both, the three dimensions of resilience and overall resilience by averaging the sub-dimensions, which were weighted for their variable-components:

$$CAI_q = \left(\sum_{i=1}^{n} w_i * subdimension_{sq}\right) / \left(\sum_{i=1}^{n} w_i\right)$$

(Equation 4: Weighted aggregation of sub-components into resilience dimensions)

Last, the indicator is validated by ascertaining correlations between dimensions, with inquired measures of wellbeing and resilience, and as predictor for evidenced coping strategies employed by the respective household.

Other weighting methods were not considered for several reasons. First, statistical weighting with principal component analysis was not suited to sample size and data distributions. Second, while the researchers in the present project closely collaborated with partner universities to reach areas with ongoing collaborations, expert weighting was not considered as allocation of budgets in weighing variables may be biased by institutional functions. Further, the number of indicators may evoke circular thinking. Last, geometric mean aggregation, where the compensability is much lower, was not considered as effect on the final indicator is difficult to comprehend. Given that indicators per se serve to indicate or inform someone about something, this aspect should be avoided wherever possible (Fritzsche et al., 2014; GIZ & EURAC, 2017).

5. Results

This section addresses the research questions. First, RQ1 (*What are the main differences between the hamlets in terms of livelihood diversification?)*, is answered by looking at demographic characteristics, income sources and farm attributes in Section 5.1. Next, RQ1-SQ1 *(Which livelihood strategies can be identified?)*, is investigated by employing the exhaustive CHAID algorithm on the very same variables to identify livelihood strategies in Section 5.1.1. The result is complemented by answering RQ1-SQ2 *(What are different motivations for taking up a specific strategy?)* in Section 5.1.2. Thereafter, RQ1-SQ3 *(How can differences in income between these strategies be explained?)* is examined in Section 5.1.3. A resilience indicator is composed and question RQ2 (*What is the level of resilience of the identified strategies?)* is elaborated on by explicating differences in sub-dimensions and overall livelihood resilience in Section 5.2. Consecutively the answer to RQ2-SQ1 (*What is an appropriate measure for validating the resilience indicator?*) seeks to confirm the indicator results in Section 5.2.1. Last, RQ3 (*Which shocks impacted the households and how did they respond?*) in Section 5.3 and RQ3-SQ1 *(Do identified strategies apply different positive or negative coping strategies?)* in Section 5.3.1 are answered to establish an empirical connection between the abstract concept of resilience and the coping strategies the households applied. Finally, Section 5.4. provides an overview of how the indicator was validated and a synthesis of the results, and confirms or rejects the three working hypotheses postulated in Section 1.5.

5.1. Results-RQ1: Differences in income and farming between villages

Substantial differences between hamlets were identified in terms of level of income and income sources, farm diversification, input intensity, as well as credit and market access. Table 9 presents summary statistics for all 35 livelihood variables, of which 26 differed significantly. Most prominent were differences in farming systems and livelihood diversification.

5.1.1. Socio-demographic characteristics: villages differ only in household size

In terms of socio-demographic characteristics, no significant differences in household-head age or education were found. The mean age of respondents was 43 years, with on average 6 years of education. Of the 78 household-heads interviewed one respondent was female. On average, the most educated member of each household in both hamlets had about 9 years of education. However, households in Penanggungan were (with a median latency of 5 members) by 1 member larger as compared to 4 members in Leksana (Ranksum, U=487.0, P(L>P)=0.320, p<0.01). The dependency ratio (49.4%) was low and differed only marginally. However, the median hired labour ratio was by 38.7pp higher in Penanggungan (42.2%) (Ranksum, U=358.0, P(L>P)=0.236, p<0.01).

More households in Leksana rated access to market higher (Likert 1-6=worst, median=2) than Penangungan (median=1) (Ranksum, U=583, P(L>P)=0.616 p<0.01), however, the difference in medians was not significant. Access to formal credits did not differ significantly. Households in both hamlets reported nearly complete access to informal credits. Only 8.3% less households in Leksana reported no easy access to informal credits (Proportion-test, p<0.1).

5.1.2. Income of households in Leksana were significantly more diversified

Income diversification was assessed in both absolute and relative terms, where for the latter negative income (i.e., losses) were not considered. In the sample, most farming system related variables follow a leptokurtic distribution that is skewed to the right with partly heavy tails (Table 9). Households in Penanggungan source, with on average 73.2%, most income from seasonal cropping, followed by off-farm activities providing on average 18.5% income (e.g., construction work or trading), while income from other sources was negligible. Contrastingly, household income in Leksana was much more diversified and differed significantly from Penanggungan in all sources (Ranksum, all p<0.01, compare Table 9, Income in shares), except fisheries which share was negligible in both hamlets. The major sources of income were animal husbandry (31.4%), off-farm activities (30.8%), seasonal cropping (27.4%) and perennial cropping (10.1%).

5.1.3. Higher income from seasonal cropping in Penanggungan

Monthly income, in absolute terms, differed between households of the two hamlets. Monthly median overall household income in Leksana (2.247 Mio IDR) was 1.2 times lower than in Penanggungan (4.369 Mio IDR). The monthly median household income from farming in Leksana (1.935 Mio IDR) was with a median difference of 42.12% (1.842 Mio IDR) not significantly lower than in Penanggungan (3.343 Mio IDR). However, the distribution differed significantly (Ranksum, U=497.5, P(L>P)=0.327 p<0.01) and the likelihood of a household in Penanggungan earning more income from farming than a household in Leksana was thus 67.3%.

Figure 5 shows the distribution of monthly household income. One household (Penanggungan) had overall negative income. However, in each hamlet four households had losses in seasonal cropping (10.25% of sample).

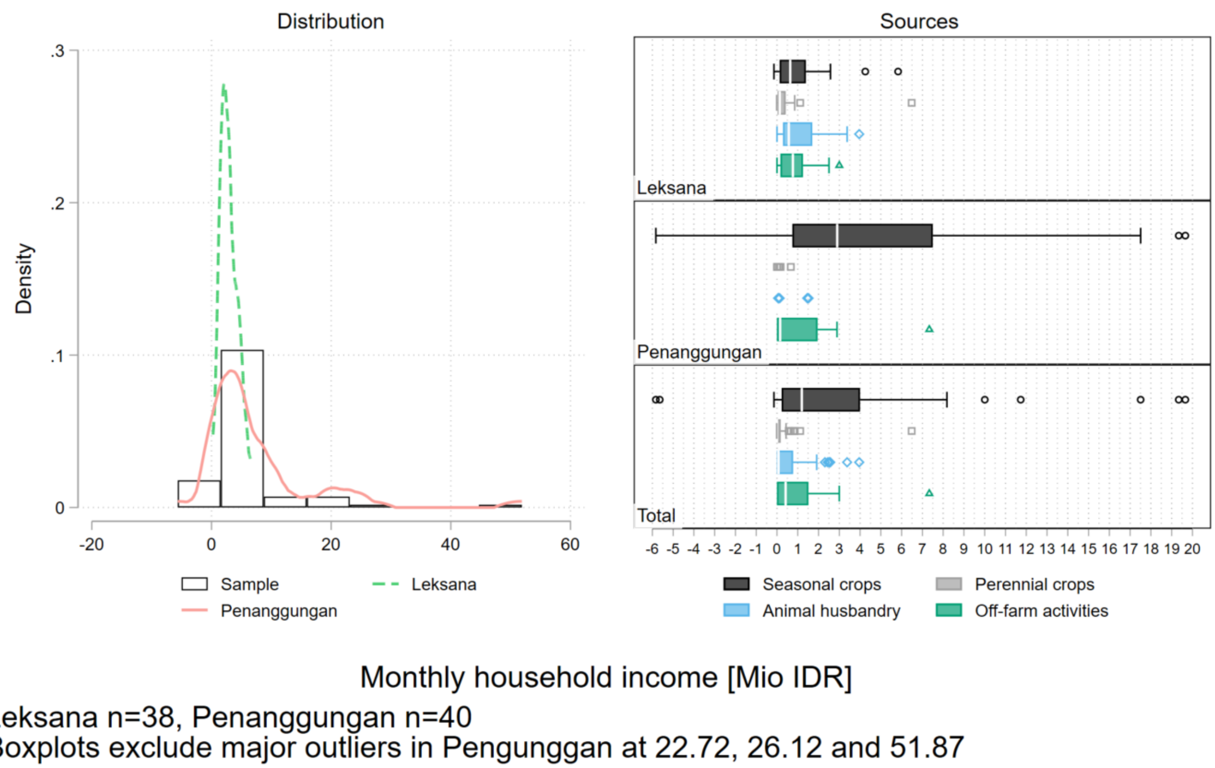

Figure 5: Monthly household income (villages)

Table 8: Descriptive for livelihood related variables (villages)

	Livelihood variables	Leksana n=38				Penanggungan n=40				Ranksum-test of distrib.		Quantile regression ($\tau = p_{50}$)	
		mean	sd	p50	iqr	mean	sd	p50	iqr	U	$P(L > P)$	Median-diff.	Std. Err
Demographic characteristics	Hh.- age (yrs)	42.921	9.903	41.000	13.000	43.250	10.794	45.000	15.000	717.0	0.472	4.000	2.556
	Hh.- education (yrs)	6.132	1.070	6.000	0.000	6.225	1.577	6.000	0.000	742.5	0.488	0.000	0.000
	H size (n)	3.842	1.001	4.000	1.000	4.700	1.418	5.000	2.500	487.0***	0.320	1.000***	0.371
	Dependency ratio (%)	0.467	0.548	0.333	0.500	0.519	0.396	0.500	0.442	640.5	0.421	0.167	0.089
	Hired labour ratio (%)	0.128	0.227	0.017	0.123	0.405	0.344	0.422	0.569	358.0***	0.236	0.387***	0.118
	Highest education in h. (yrs)	9.158	2.086	9.000	0.000	8.700	2.472	9.000	3.000	657.5	0.567	0.000	0.535
Income in shares*	Seasonal crops (%)	0.274	0.250	0.202	0.319	0.732	0.346	0.909	0.420	256.0***	0.168	0.701***	0.052
	Perennial crops (%)	0.101	0.118	0.053	0.169	0.003	0.010	0.000	0.000	170.0***	0.888	-0.059*	0.016
	Animal husbandry (%)	0.314	0.241	0.294	0.361	0.040	0.135	0.000	0.000	133.0***	0.912	-0.299***	0.048
	Fisheries (%)	0.002	0.008	0.000	0.000	0.015	0.097	0.000	0.000	731.0	0.519	0.000	0.000
	Off-farm activities (%)	0.308	0.277	0.237	0.525	0.185	0.279	0.039	0.298	508.0**	0.666	-0.184**	0.085
	Total farm activities (%)	0.692	0.277	0.763	0.525	0.815	0.279	0.961	0.298	508.0**	0.334	0.184**	0.085
Income in absolutes*	Seasonal crops (Mio IDR/month)	0.998	1.239	0.637	1.260	6.780	10.147	3.771	7.309	338.0***	0.222	3.323***	1.046
	Perennial crops (Mio IDR/month)	0.408	1.052	0.134	0.384	0.024	0.109	0.000	0.000	213.0***	0.860	-0.135***	0.038
	Animal husbandry (Mio IDR/month)	1.004	1.015	0.569	1.406	0.118	0.397	0.000	0.000	130.0***	0.914	-0.579***	0.116
	Fisheries (Mio IDR/month)	0.004	0.024	0.000	0.000	-0.001	0.023	0.000	0.000	733.0	0.518	0.000	0.000
	Off-farm activities (Mio IDR/month)	0.822	0.781	0.766	1.083	0.857	1.427	0.150	1.875	590.0*	0.612	-0.631***	0.210
	Total farm (Mio IDR/month)	2.134	1.528	1.935	2.183	6.825	9.969	3.343	6.418	497.5***	0.327	1.842	1.114
	Per capita income (Mio IDR/month)	1.183	0.826	1.093	0.610	2.425	3.107	1.229	1.609	585.0*	0.385	0.176	0.242
Assets, diversification and intensification	Operated land (ha)	0.786	0.480	0.710	0.553	1.000	0.827	0.805	1.030	691.0	0.455	0.110	0.201
	Livestock ownership (TLU)	0.931	0.760	0.770	1.000	0.117	0.348	0.000	0.000	154.5***	0.898	-0.800***	0.081
	Income diversity	1.075	0.407	1.079	0.725	0.724	0.298	0.603	0.450	338.0***	0.778	-0.453***	0.156
	Crop diversity	2.758	0.873	2.948	1.061	1.472	0.738	1.421	0.615	201.0***	0.868	-1.467***	0.227
	Livestock diversity	1.208	0.505	1.093	0.528	0.132	0.356	0.000	0.000	114.0***	0.925	-1.100***	0.097
	Agroforestry land (%)	68.605	35.285	100.000	70.000	5.200	16.755	0.000	1.500	44.5***	0.971	-100.000***	0.000
	Seasonal crops (n)	3.632	1.460	3.500	1.000	3.500	0.987	3.500	1.000	759.5	0.500	-1.000***	0.369
	Perennial crops (n)	2.921	1.496	3.000	2.000	0.400	1.081	0.000	0.000	115.5***	0.924	-3.000***	0.366
	Value trees crops (n)	1.974	1.896	1.500	3.000	0.600	1.374	0.000	0.000	388.0***	0.745	-2.000***	0.449
	Total type of plants (n)	8.526	3.790	8.000	5.000	4.500	2.612	4.000	2.000	242.5***	0.841	-4.000***	0.986
	Input: fertilizer (Mio IDR/ha*month)	0.221	0.209	0.167	0.211	1.540	2.373	0.881	0.76	164.0***	0.108	0.736***	0.107
	Input: pesticides (Mio IDR/ha*month)	0.107	0.135	0.062	0.131	1.097	1.890	0.400	0.826	281.0***	0.185	0.338***	0.096
	Input: labour (Mio IDR/ha*month)	0.228	0.691	0.000	0.056	0.488	0.716	0.226	0.497	395.0***	0.260	0.229**	0.087
	Input: seeds (Mio IDR/ha*month)	0.118	0.231	0.045	0.056	1.962	4.734	0.489	1.310	209.0***	0.138	0.441***	0.150
Market/ credit	Market access (1-6, 1=best)	2.053	1.114	2.000	1.000	1.575	0.675	1.500	1.000	583.0***	0.616	0.000	0.249
												Proportion-test	
	Informal credit access (yes=1)	0.917	0.280	1.000	0.000	1.000	0.000	1.000	0.000	660.0***	0.458	-0.083*	0.045
	Formal credit access (yes=1)	0.471	0.507	0.000	1.000	0.615	0.493	1.000	1.000	567.0***	0.428	-0.145	0.117

Note: Significance threshold α at 0.1, 0.5** and 0.01***; $P(L > P)$= Stochastic dominance of Leksana over Penanggungan; U: Lower pairs of ranks, Hh.= household head, ha=hectare, TLU= Tropical Livestock Unit, IDR = Indonesian Rupiah (average exchange rate 2018 IDR/USD=14,481.00 or; 2018 PPP IDR/USD = 4759.089 (OECD, 2020), Diversity measures are calculated as 1/Simpson index and for crops are based on crop revenue, for livestock on TLU and for income on IDR; *Income share does not consider negative income. .*

The median monthly income from seasonal cropping in the two hamlets of Leksana (0.637 Mio IDR) and Penanggungan (3.771 Mio IDR) differed significantly by 83.11 pp (3.323 Mio IDR, p<0.01). Similarly, the likelihood of a household in Leksana having a higher income from seasonal cropping than in Penanggungan was low with 22.2% (Ranksum, U=338, p<0.01). On the other hand, Leksana had a higher income from perennial crops (median difference 0.135 Mio IDR, p<0.01), animal husbandry (median difference 0.579 Mio IDR, p<0.01) and off-farm activities (median difference 0.631 Mio IDR). Median income from off farm activities was by 0.631 Mio IDR or 80.42pp (median-difference, p<0.01) higher in Leksana (0.766 Mio IDR) than in Penanggungan (0.150 Mio IDR).

5.1.4. No significant difference in monthly per capita income between Leksana and Penanggungan

Median monthly per capita income in Leksana was with 1.093 Mio IDR only slightly below the median in Penanggungan (1.229 Mio IDR). The measure of stochastic dominance reveals that the likelihood of an individual in Leksana having a higher per capita income than in Penanggungan is low with 38.5% (Ranksum, U=585, p<0.1). The differences in means, where average per capita income in Penanggungan is almost twice as high as in Leksana, stems from the empirically justifiable outliers in the sample. Figure 6 shows the cumulative distribution of the per capita income compared to regional wages (left) and poverty lines (right).

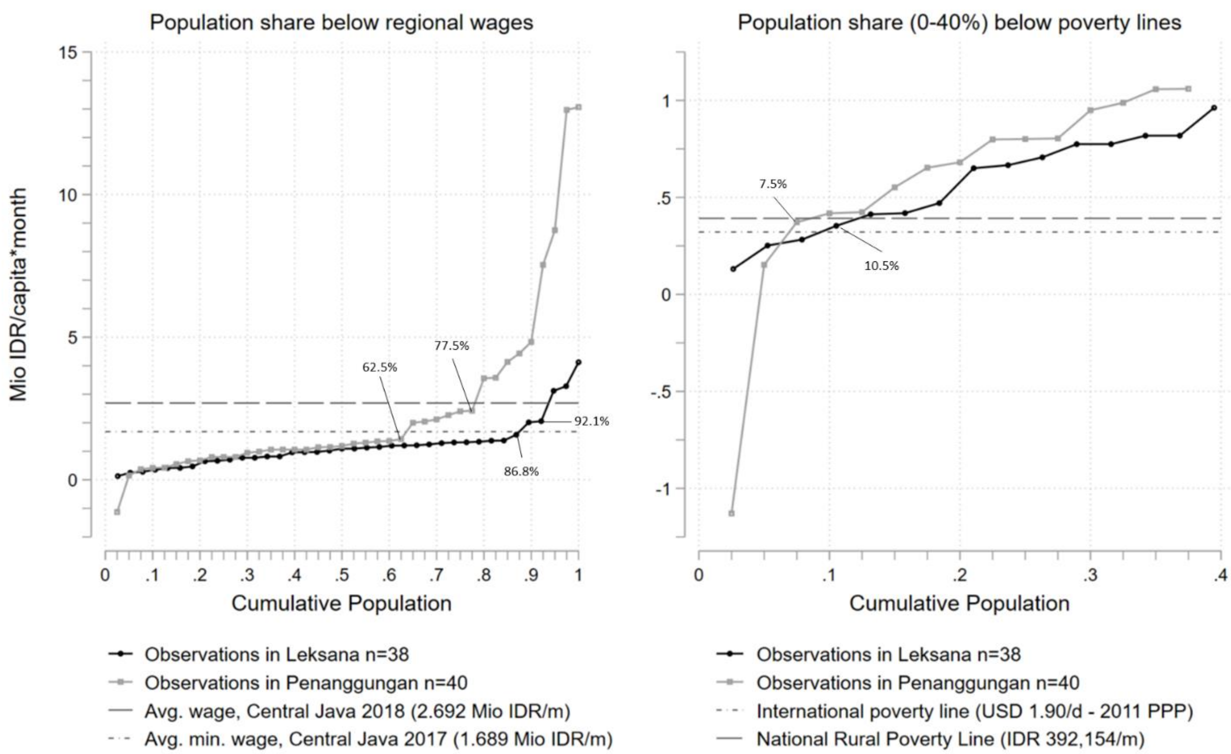

Figure 6: Comparing mean regional per-capita wages and poverty lines

Note on sources: Survey data; Average wage by CEIC, (n.d.); minimum wage by Huda, (2017), and poverty lines by OECD, (2020)

Median monthly per capita income in the hamlets and the sample (1.140 Mio IDR) was below both the average regional wage (CEIC, n.d.), as well as the district-specific minimum wage (Huda, 2017) (left graph). Individual percentage values highlight the population share below the threshold. Almost three thirds of the sample (74.46%) did not cross either comparison threshold (Sign-test, p<0.01, one-tailed). However, poverty as defined by the national rural poverty line was with a headcount ratio of 8.97% low in the sample (right graph; Signtest, p<0.01, one-tailed) and below national average of 13.10% in September 2018 (OECD 2019). Thus, while most households earn less than regional wages, a minor part of the sample is below the national rural poverty line.

5.1.5. Significantly higher levels of farm and income diversification in Leksana

Generally, livelihoods were significantly more diversified in Leksana as compared to Penanggungan (Figure 7). Whereas operated land area was comparable with on average 0.786 ha in Leksana and 0.827 ha in Penanggungan, livestock ownership was with 0.931 TLU (Tropical Livestock Units) by about 7.9 times higher in Leksana than in Penanggungan (see Figure 7). The likelihood of a household in Leksana owning more livestock than a household in Penanggungan was 89.8% (Ranksum, U=154.5, p<0.01).

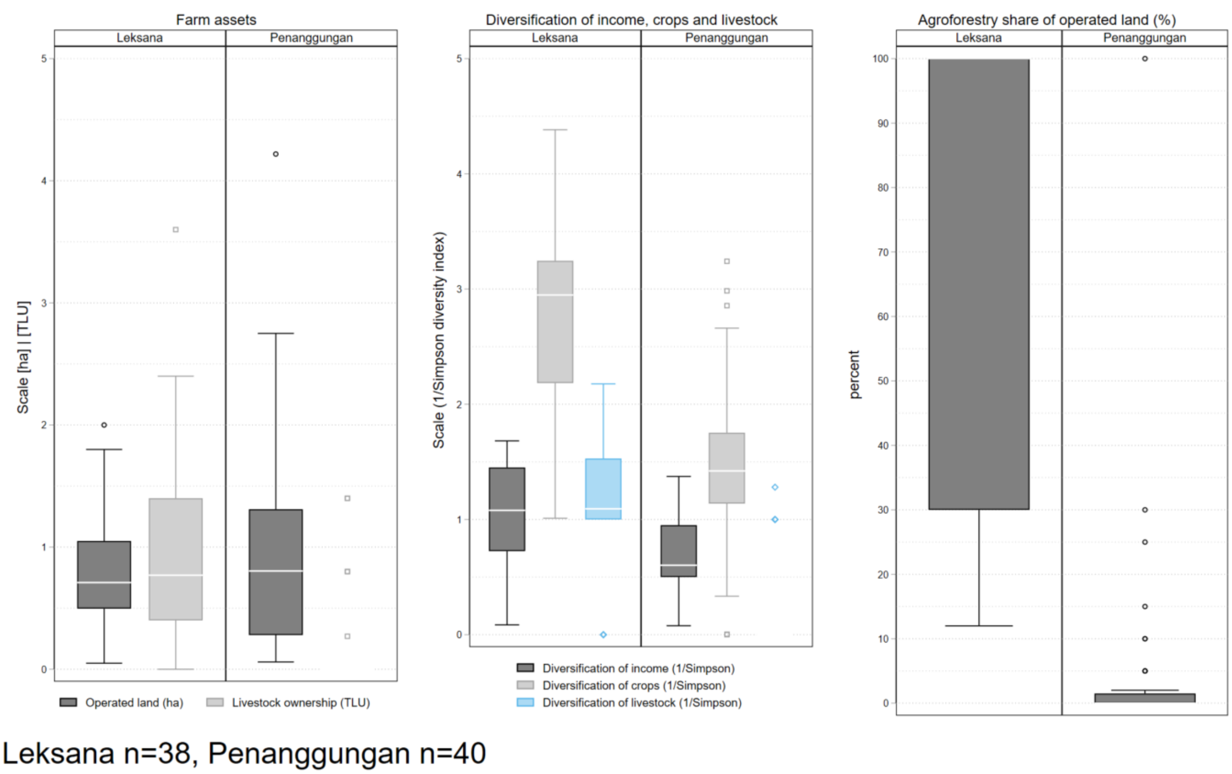

Figure 7: Farm assets and diversification of income, crops and livestock

Further, income, crop, and livestock diversity (see Figure 7 and Table 9) were significantly more pronounced in Leksana (Ranksum-test, all p<0.01, compare Table 9). The most prominent difference between the two villages was the prevalence of agroforestry in the farming systems. Whereas intercropping was common in both hamlets, on average Leksana smallholders used agroforestry in about 68.61% (median of 100%) of their operated area in contrast to Penanggungan where the average share of agroforestry was 5.2% (median of 0%) (Ranksum-test, U=44.5, p<0.01). The likelihood of a household having a higher percentage of agroforestry in Leksana compared to Penanggungan was 97.1%. This result is corroborated by the fact that more than twice as many varieties were planted in households in Leksana compared to Penanggungan (median difference of 4, p<0.01; Ranksum, U=242.5, P(AF>C)=0.841, p<0.01) owing largely to differences in value trees and perennial crops. Across all three seasons the number of seasonal crops grown did not differ significantly between the two villages.

5.1.6. Households in Penanggungan use significantly more input

The difference in share of income sources, height of income and farm diversification is underlined by the difference in input between the two villages. All four, seed input, labour cost, pesticide and fertilizer input expenditure were multiple times higher in Penanggungan than in Leksana (Ranksum, all $p<0.01$, compare Table 8 and Figure 8).

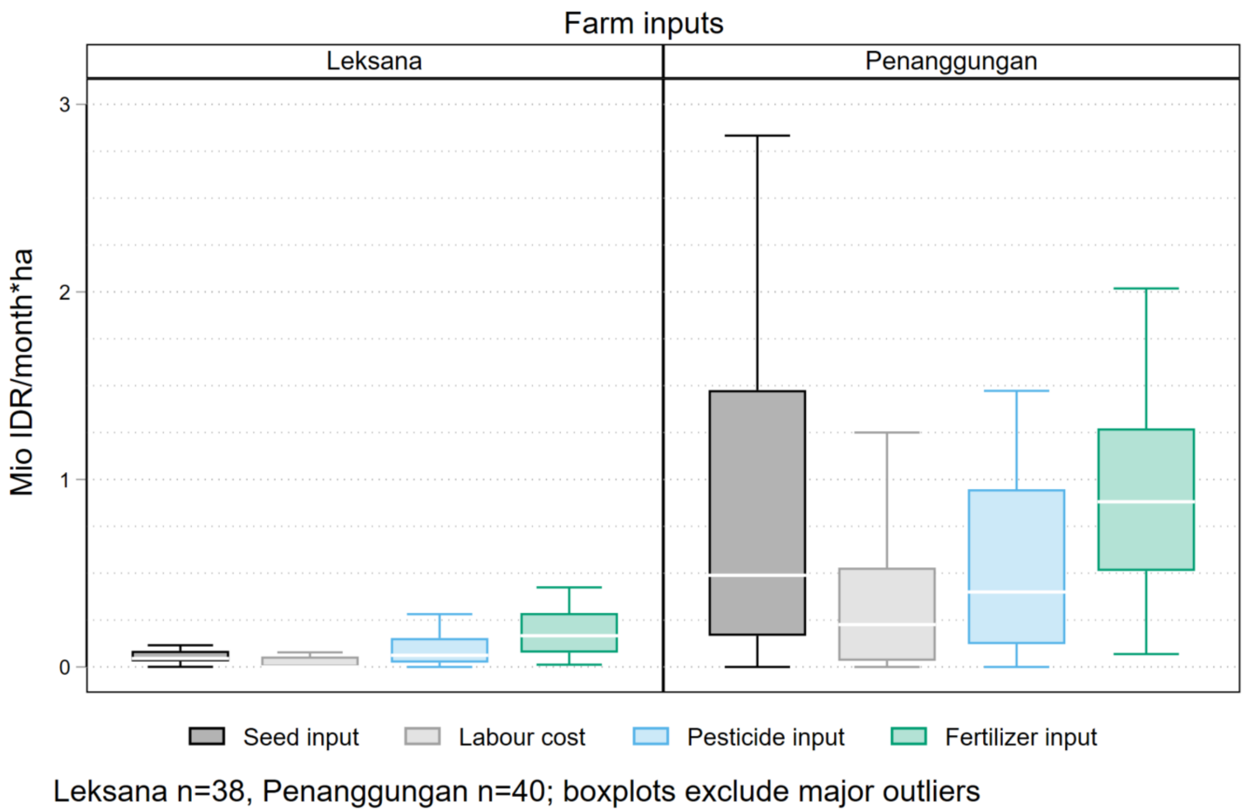

Figure 8: Farm inputs: seeds, labour, pesticides and fertilizer

Further insights into the farming system and income are provided after identification of livelihood strategies.

5.1.7. Results-RQ1-SQ1: Two distinct livelihood strategies: Conventional and Agroforestry

Two major types of livelihood strategies were identified applying the analytical strategy outlined in Chapter 4: *Agroforestry* (Type 1) and *Conventional* (Type 2).[7] The final decision tree suggested 5 nodes, of which 3 were terminal nodes (Figure 9).

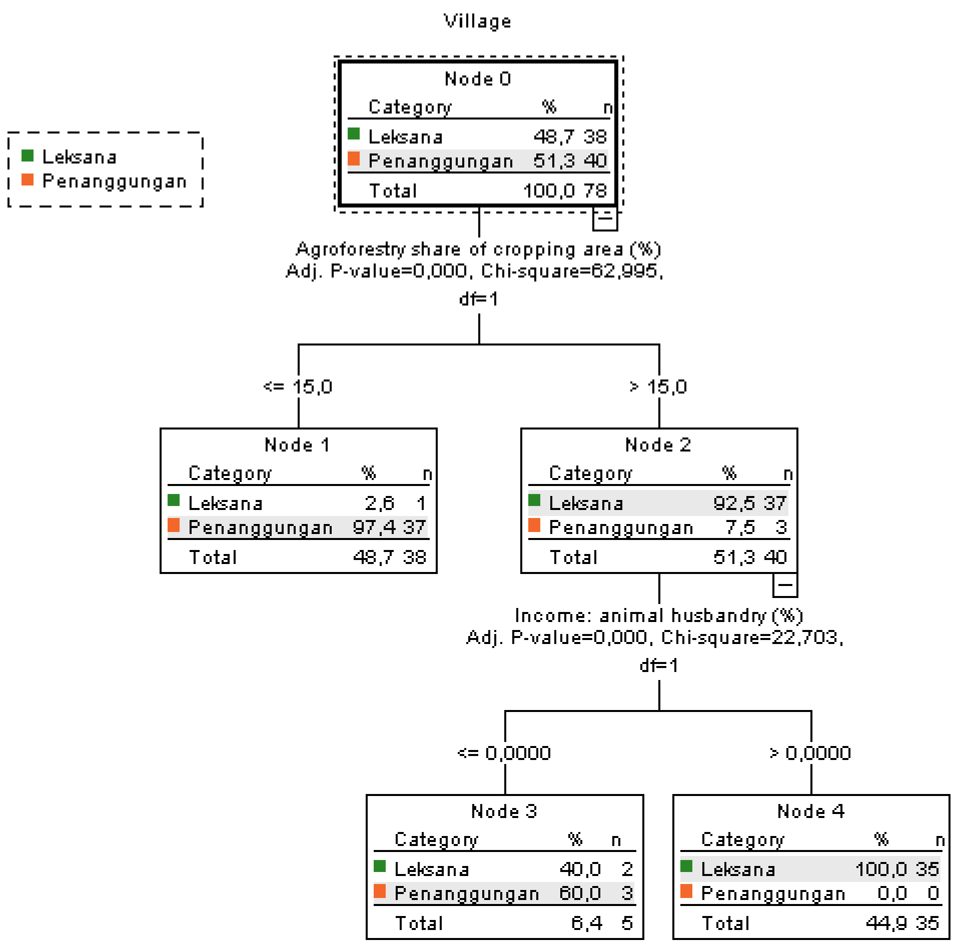

Figure 9: Exhaustive CHAID classification tree model

First, households of the villages differ whether they have more or less than 15% of agroforestry (Pearson's $\chi^2 = 62.995$, p<0.01). A total of 38 households (1 in Leksana and 37 in Penanggungan) have 15% or less than 15% of their area with agroforestry and fall under *Conventional*. Households having more than 15% of their operated area with agroforestry are categorized into the *Agroforestry* group (40 households, 37 in Leksana and 3 in Penanggungan). Second, the model splits *Agroforestry* in two-subtypes according to

[7] Consistently the terms *Agroforestry* and *Conventional* are employed in italics throughout the text, while the terms groups and types are added and used interchangeably to address the two respective livelihood strategies while preserving text flow.

income from animal husbandry (Type 2a and Type 2b). The model differentiates between those with 0 income share in animal husbandry (5 households, 2 in Leksana and 3 in Penanggungan) and those with more than 0 (35 households in Leksana) (Pearson χ^2 =22.703, p<0.01).

The sample was thus split at two levels: first, the share of operated land with agroforestry, and second, the share of animal husbandry in total income. Overall, 96.2% of the sample can be explained by the model (see Table 9). The risk estimate for predictive accuracy with the re-substitution method was very low 0.038 [0.022] meaning that the tree misclassifies 3.8% of households. The results of the classification table are consistent with the risk estimate. The table shows that the model classifies approximately 96.2% of households correctly. While 100% of observations in Penanggungan are correctly classified, only 92.1% are in Leksana, which shows a certain overlap of livelihood strategies that the model cannot fully distinguish. To generalize the tree structure to a larger population, cross-validation was used that divides the sample into several subsamples (folds). The cross-validated risk-estimate is the average of risks across all sub-samples (ibid.). Cross-validation with 10 folds estimated the risk of misclassification across all trees with 0.09 [0.032].

Table 9: Classification table for the exhaustive CHAID classification tree model

Observed	Predicted		
(n=78)	Leksana	Penanggungan	Percent correct
Leksana (n=38)	35	3	92,1%
Penanggungan (n=40)	0	40	100,0%
Overall Percentage	44,9%	55,1%	96,2%

The splits resulting from the exhaustive CHAID model are congruent with being the most dividing variables (both effect size and statistical significance) between the two villages determined with the non-parametric tests in the previous section (compare Table 8) in the initial bivariate analysis of the hamlets. Generally, between the hamlets and the identified major types a close association exists (χ^2 test of independence, Pearson $\chi^2 = 62.995$, Cramér's V=0.89, p<0.01). For further analysis, the two major types of *Agroforestry* and *Conventional* are maintained as analytical categories, considering that only two households engaged in agroforestry did not keep livestock, limiting the value of the differentiation for generalization. Further, maintaining only the main categories offers the possibility for robust analysis due to evenly distributed sample sizes.[8]

[8] While the Kruskal-Wallis test offers in principle the possibility to test groups with $n \geq 5$, it was not considered due to the uneven distribution.

5.1.8. Results-RQ1-SQ2: Building an "Economic Safety-Net" is the strongest reason for implementing agroforestry

Given that the survey was adjusted after initial interviews and based on preliminary results, it asked in detail for the motivation to use or not use agroforestry as a strategy. As the differentiation into sub-groups was made at the threshold of 15% of land having agroforestry, the *Conventional* group included 8 smallholders with low levels of agroforestry were below 15%.

The responses to the open question (free listing) were aggregated into seven types of reasons for doing agroforestry (see Table 10), with all 40 households in *Agroforestry* and the respective 8 in *Conventional* providing a reason (total responses 62). Having agroforestry as an economic safety net was by far the most frequent response (52.94% of responses and 67.5% of households in *Agroforestry*). This reason was not given at all in *Conventional*. However, in both groups soil and water conservation (SWC) related reasons were mentioned. In *Agroforestry* 32.5% of observations used this motivation to use agroforestry. In *Conventional* all 8 observations that practice agroforestry provided SWC as motivation.

Table 10: Motivations for agroforestry

Responses:	Agroforestry			Conventional			Sample			Corr. with Agroforestry
Reasons for Agroforestry	Count of responses	**Obs. (%)**	Resp. (%)	Count of responses	**Obs. (%)**	Resp. (%)	Count of responses	**Obs. (%)**	Resp. (%)	Pearson's ϕ
Food for livestock	1	2.5	1.96	0	0	0	1	1.28	1.64	0.111
Convenience	2	5.0	3.92	0	0	0	2	2.56	3.28	0.158
Additional income	3	7.5	5.88	0	0	0	3	3.85	4.92	0.195*
Construction material	2	5.0	3.92	1	2.63	10	3	3.85	4.92	0.062
Local convention / tradition	3	7.5	5.88	1	2.63	10	4	5.13	6.56	0.110
Soil and water conservation	13	32.5	25.49	8	21.05	80	21	26.92	34.43	0.129
Economic safety net	27	67.5	52.94	0	0	0	27	34.62	44.26	0.709***
Total responses	51	127.5	100	10	26.32	100	61	78.21	100	
Total cases	40			38			78			

Note: Significance threshold α at 0.1, 0.5** and 0.01***;*

Next, the reasons for agroforestry were investigated for their correlation with the livelihood strategy, with Pearson's ϕ, as binomial logistic regression was not possible due to multi-collinearity. Economic safety net (Pearson's $\phi = 0.709$, p<0.01) and Additional income (Pearson's $\phi = 0.195$, p<0.1) were the motivations with the highest binomial correlation with *Agroforestry*. Thus, economic reasons were main motivations to engage in agroforestry.

Conversely, the reason against implementing agroforestry was assessed (see Table 11). Logically, no respondent of the *Agroforestry* group provided a reason against implementation. In the *Conventional* group 24.36% of respondents suspected a negative impact on crops from shade and water retention (61.29% of responses). Next, but less prominent, lower profitability of agroforestry systems was reported as reason against implementation. Here, 8.97% of respondents did not consider agroforestry as profitable strategy.

Table 11: Motivations against agroforestry

Responses:	Agroforestry	Conventional			Sample			Correlation with Conventional
Reasons against agroforestry	Count of responses	Count of responses	**Obs. (%)**	Pearson's ϕ	Count of responses	**Obs. (%)**	Resp. (%)	Pearson's ϕ
Local convention / tradition	0	1	2.63	3.23	1	1.28	3.23	0.117
Soil fertility decrease	0	2	5.26	6.45	2	2.56	6.45	0.166
Difficulty of change (legally/technically)	0	2	5.26	6.45	2	2.56	6.45	0.166
Less profitable	0	7	18.42	22.58	7	8.97	22.58	0.322***
Negative impact on crops (shade and water retention)	0	19	50	61.29	19	24.36	61.29	0.582***
Total responses	0	31	81.58	100	31	39.74	100	
Total cases	40	38			78			

Note: Significance threshold α at 0.1, 0.5** and 0.01***;*

Amongst all reasons against agroforestry, profitability considerations (Pearson's $\phi = 0.322$, p<0.01) and the belief of negative impact of trees on crops through shade and water retention (Pearson's $\phi = 0.582$, p<0.01), were the only two significant reasons having correlation with *Conventional* farming style.

The difference in responses suggest that household in the Agroforestry group adhere to a risk averse long-term strategy. This may result in more resilience as will be investigated in Section 5.2. where a closer look on agroecological resilience against natural hazards and market shocks is provided.

5.1.9. Results-RQ1-SQ3: Differences in farming and income of the livelihood strategies

Per capita income between livelihood strategies does not differ

Households following the *Conventional* strategy tended to have a higher median monthly income than households from the *Agroforestry* type (Ranksum, U=585.5, P(AF>C)=0.385, p<0.1; see Figure 10). The median difference between *Agroforestry* (2.470 Mio IDR per month) and *Conventional* (3.584) was 31.08pp or 1.505 [0.842] Mio IDR per month (p<0.1).

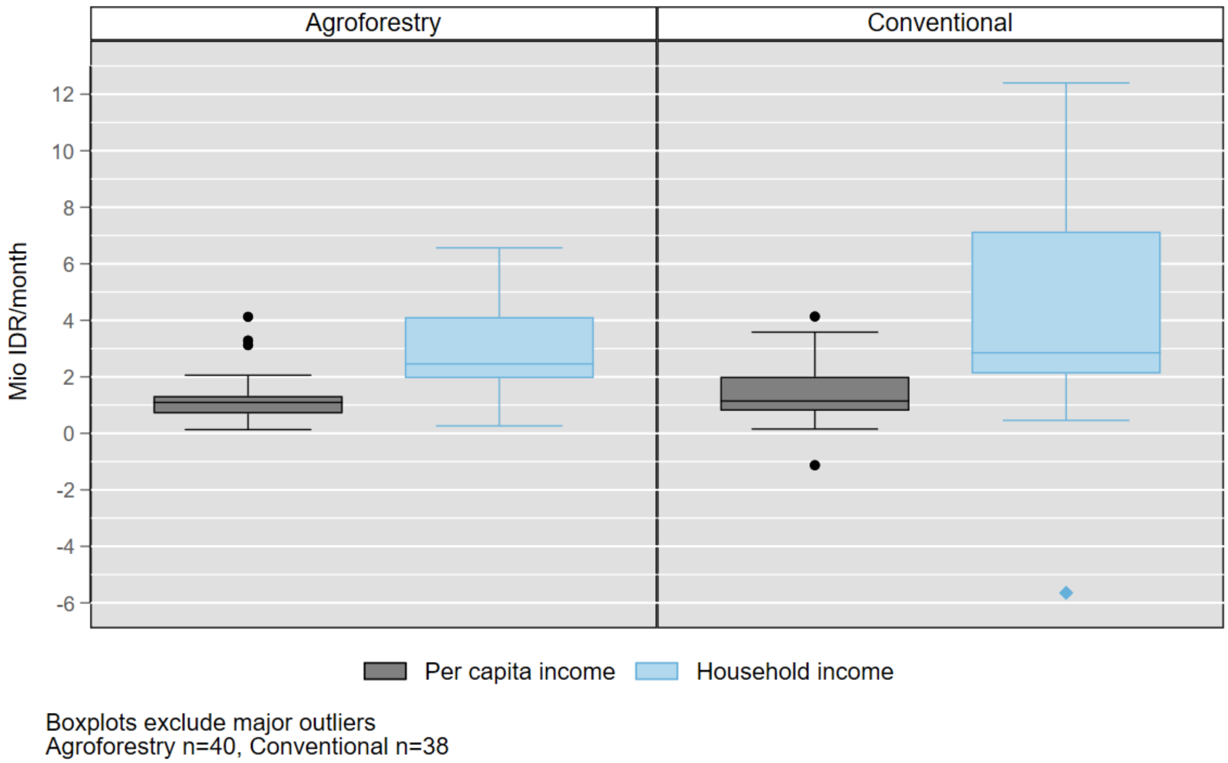

Figure 10: Monthly household and per capita income of livelihood strategies

However, monthly median per capita income between the two groups did not differ significantly (Ranksum, U=604, P(AF>C)=0.397, p=0.119). For *Agroforestry* and *Conventional*, the median latency of monthly per capita income was 1.093 Mio IDR and 1.229 Mio IDR respectively, and the median difference of 0.176 [0.237] was not significant (p=0.460). Thus, it can be concluded that while income is larger in households following the *Conventional* strategy, there is no statistically significant difference between the two groups as regards per capita income.

Differences in income sources between strategies

In *Agroforestry* monthly mean incomes were 2.329 Mio IDR (29.24%) from seasonal crops, 0.943 Mio IDR (29.49%) from keeping livestock, 0.843 (31.56%) from off-farm activity, 0.384 Mio IDR (9.49%) from perennial crops. In Conventional, by far the largest monthly mean income was 5.683 Mio IDR (73.65%) from seasonal crops, followed by off farm activity with 0.843 Mio IDR (17.09%), 0.135 Mio IDR (4.62%) from animal husbandry and 0.029 Mio IDR (0.39%) from perennial crops. Figure 11 and Figure 12 show the share of income sources in relation to total household income and distributions of absolute income in the two strategies.

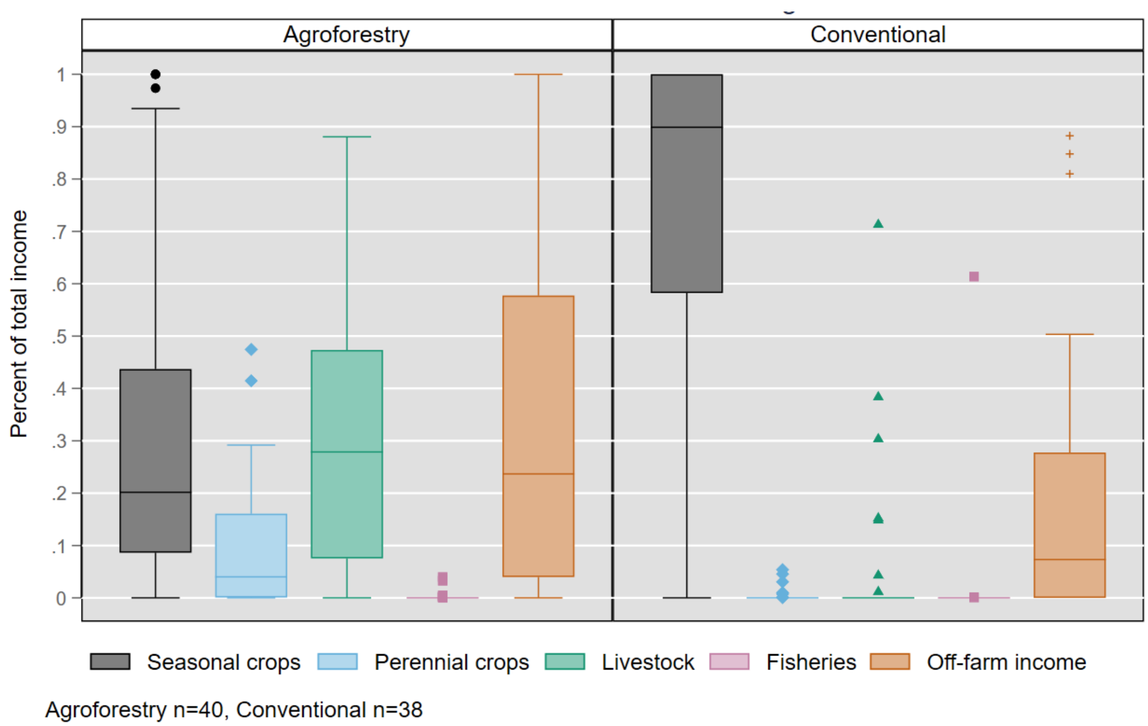

Figure 11: Shares of income sources from livelihood strategies

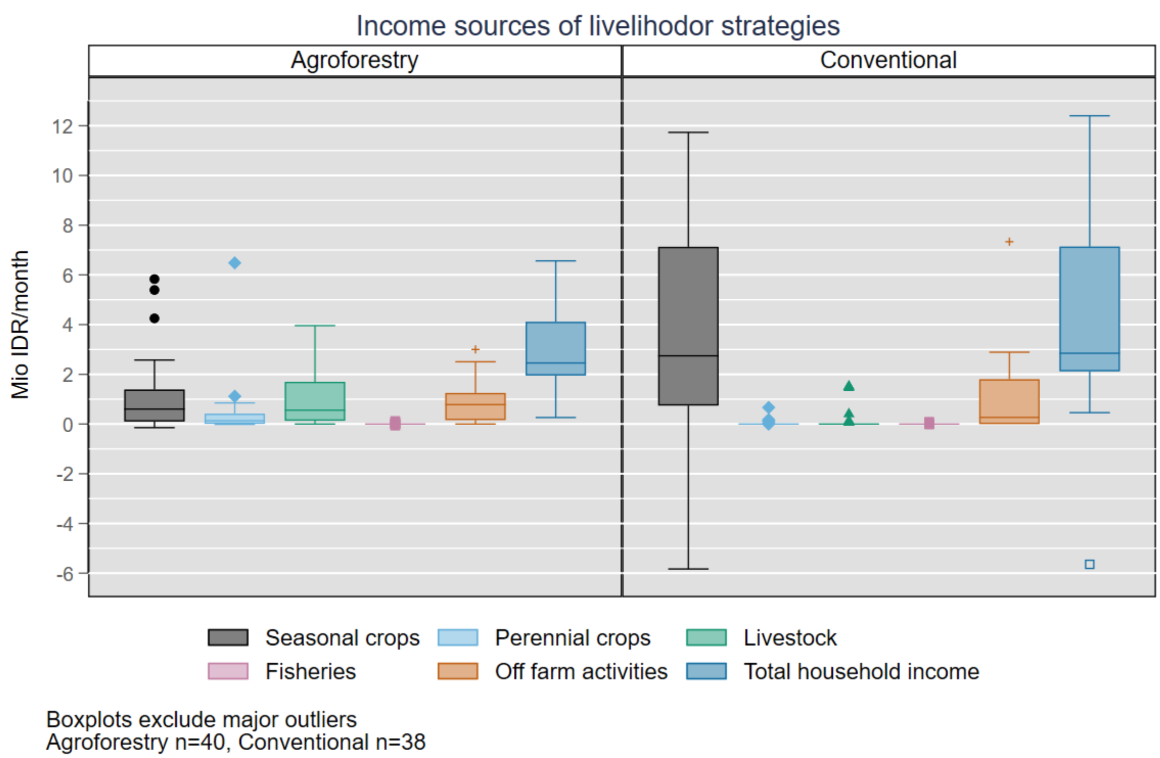

Figure 12: Income from different sources of livelihood strategies

Differences in cropping systems: Seasonal crops

The analysis of seasonal crops centred around five major varieties: potatoes, maize, cabbage, chilli, and carrots (both tubers and seeds as produce). Figure 13 provides an overview on the distribution of income of the five major cash crops.

In the *Agroforestry* group, the major share of average monthly household income per hectare came on average as 44.43% chilli with 10.764 Mio IDR (median=6.389), followed by the mean share of income of 23.41% from cabbage with 6.671 Mio IDR (median=3.260), mean share of 13.37% from maize with 1.588 Mio IDR (median=1.018), and the mean share of 7.28% from potatoes with 11.389 Mio IDR (median=0) and a mean share of 5% from beans with 1.016 Mio IDR (median=0).

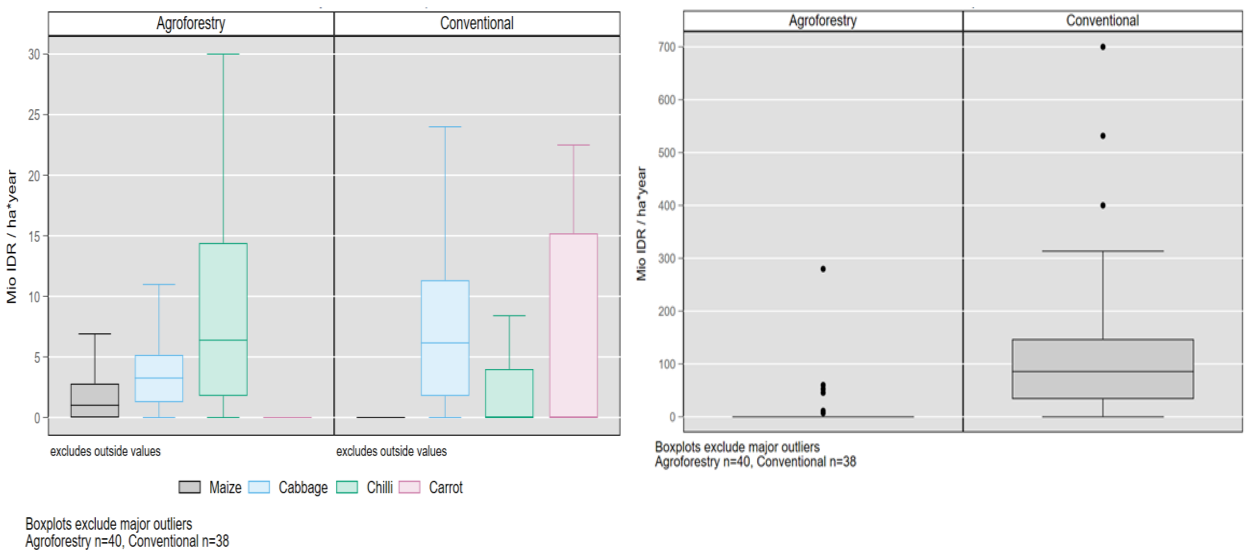

Figure 13: Revenue from common crops (left) and potato (right)

In the *Conventional* group, the majority of monthly per hectare income from seasonal cropping consisted of 69.31% from potatoes with 130.246 Mio IDR (median=85.55), mean share of 12.54% from cabbage with 9.279 (median=6.3889) mean share of 8.19% from carrots with 13.447 Mio IDR (median=0) and mean share of 5.72% from chilli with 10.414 Mio IDR (median=0).

Table 12 shows prices, yields and revenues of respective strategies. Prices did not differ significantly between the two groups. However, farmers in *Agroforestry* harvested significantly more maize and chilli but C*onventional* had significantly higher yields and, therefore, revenues from potatoes and carrots.

Table 12: Seasonal crops: prices, yields and income

	Agroforestry				Conventional				Ranksum-test of distributions		Quantile regression at median	
Crop	mean	sd	p50	iqr	mean	sd	p50	iqr	U	P(AF>C)	Med.-diff.	Std. Err.
					Average prices (IDR/kg							
Maize	5357.143	814.875	5000.000	0.000	7000.000	.	7000.000	0.000	3.0	0.107	2000.000	
Cabbage	4326.910	10484.160	1500.000	1166.667	5578.571	17184.570	1000.000	1000.000	181.0	0.625	-500.000	326.721
Chilli	12730.600	4927.202	14222.220	5000.000	10702.610	4779.083	10000.000	8000.000	207.0	0.600	-4222.222	2697.444
Potato	20739.120	31533.130	7750.000	4534.694	7477.561	2525.233	8000.000	2389.954	95.0	0.572	0.000	1304.912
Carrot	8380.952	11918.160	1500.000	20642.860	16655.460	37819.270	2125.000	6041.667	11.0	0.458	1000.000	3163.023
					Average yield in three seasons (kg/year)							
Maize	286.909	307.913	203.550	490.547	8.311	51.231	0.000	0.000	247.0***	0.838	-200.000**	77.457
Cabbage	2884.863	9292.878	502.516	2505.198	4692.453	9805.950	400.000	6000.000	698.5	0.460	-133.333	257.299
Chilli	982.534	1478.259	483.333	871.107	845.498	2502.563	0.000	466.667	399.5***	0.737	-466.667***	150.921
Potato	1274.617	5656.805	0.000	0.000	16034.290	13715.010	13732.960	17846.150	77.0***	0.051	13823.070***	1870.076
Carrot	1681.447	9347.334	0.000	0.000	3958.346	16439.740	0.000	0.000	657.0*	0.432	0.000	.
					Average revenue (Mio IDR/year)							
Maize	1.588	1.786	1.018	2.800	0.058	0.359	0.000	0.000	250.0***	0.836	-1.000**	0.387
Cabbage	6.671	14.988	3.260	3.894	9.791	13.199	6.158	9.548	578.0*	0.380	2.983*	1.675
Chilli	10.764	12.530	6.389	12.611	10.414	28.831	0.000	4.000	366.0***	0.759	-6.111***	1.896
Potato	11.389	45.755	0.000	0.000	130.246	150.595	85.550	113.316	130.0***	0.088	93.600***	21.203
Carrot	2.763	14.072	0.000	0.000	13.447	30.770	0.000	15.200	497.0***	0.327	0.000	

Differences in cropping systems: Perennial crops

Incomes from perennial crops in *Conventional* were negligible except for minor outliers. Figure 14 shows the distribution of income from perennial crops for the two strategies.

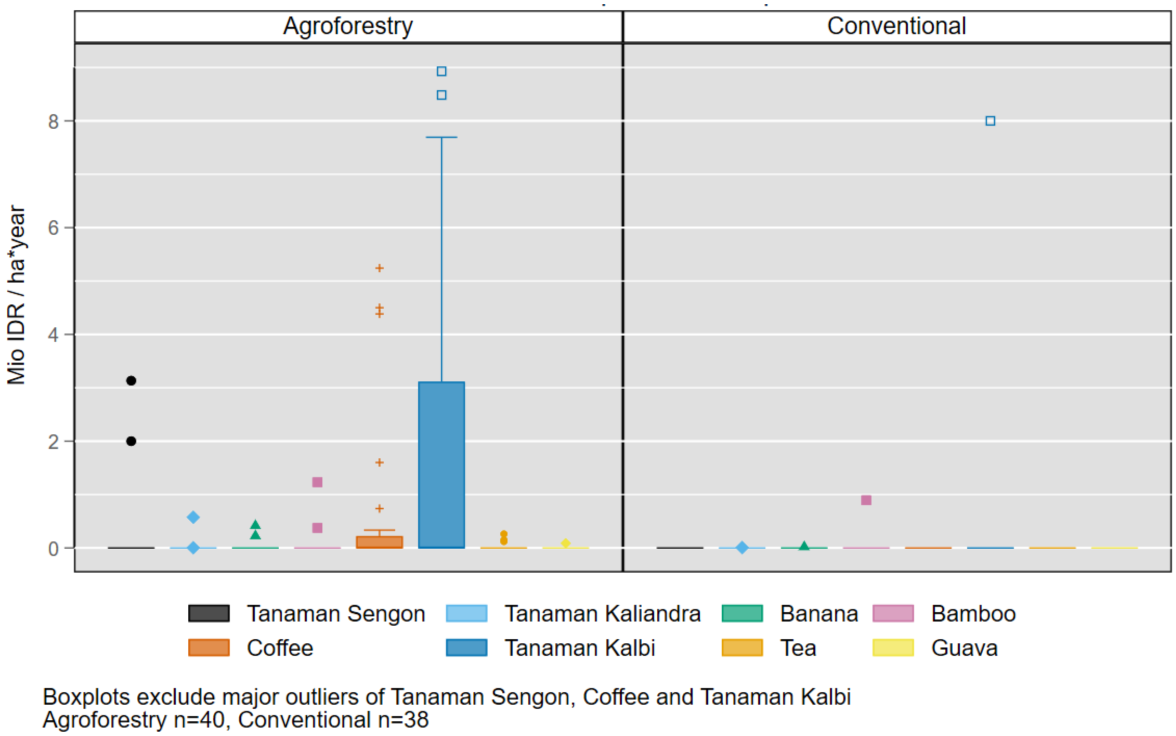

Figure 14: Income from perennial crops

In *Agroforestry*, about 0.384 Mio IDR (9.49%) of income came from perennial crops. Of these, on average, more than half (51.72%) came from value timber tree species Tanaman Kalbi (*Paraserianthes falcataria*), 22.17% from Coffee (Robusta and Arabica), value timber tree species Tanaman Sengon (*Albizia chinensis*) with 12.19%, and 6.23% from Tanaman Kaliandra (*Calliandra calothyrsus*) a leguminous tree species used for animal feed. An overview of revenues is provided in Table 13.

Table 13: Revenues from most important perennial crops (Mio IDR/ha year)

	Agroforestry				Conventional			
Crop/Tree	mean	sd	p50	iqr	mean	sd	p50	iqr
Tanaman Sengon	1.439	6.761	0.000	0.000	0.000	0.000	0.000	0.000
Tanmana Kaliandra	0.068	0.268	0.000	0.000	0.000	0.001	0.000	0.000
Banana	0.035	0.139	0.000	0.000	0.001	0.003	0.000	0.000
Bamboo	0.040	0.202	0.000	0.000	0.023	0.145	0.000	0.000
Coffee	0.848	2.253	0.000	0.255	0.000	0.000	0.000	0.000
Tanaman Kalbi	3.862	8.638	0.063	4.264	0.211	1.298	0.000	0.000
Tea	0.014	0.051	0.000	0.000	0.000	0.000	0.000	0.000
Guava	0.002	0.014	0.000	0.000	0.000	0.000	0.000	0.000

Conventional strategy used significantly more seed, labour, pesticide and fertilizer inputs

Similar to differences between the villages, monthly levels of input per ha differed drastically between the identified livelihood strategies. Total median monthly expenditure for farming was 0.35 Mio IDR in *Agroforestry* and differed by 2.88 Mio IDR in *Conventional* (Figure 15).

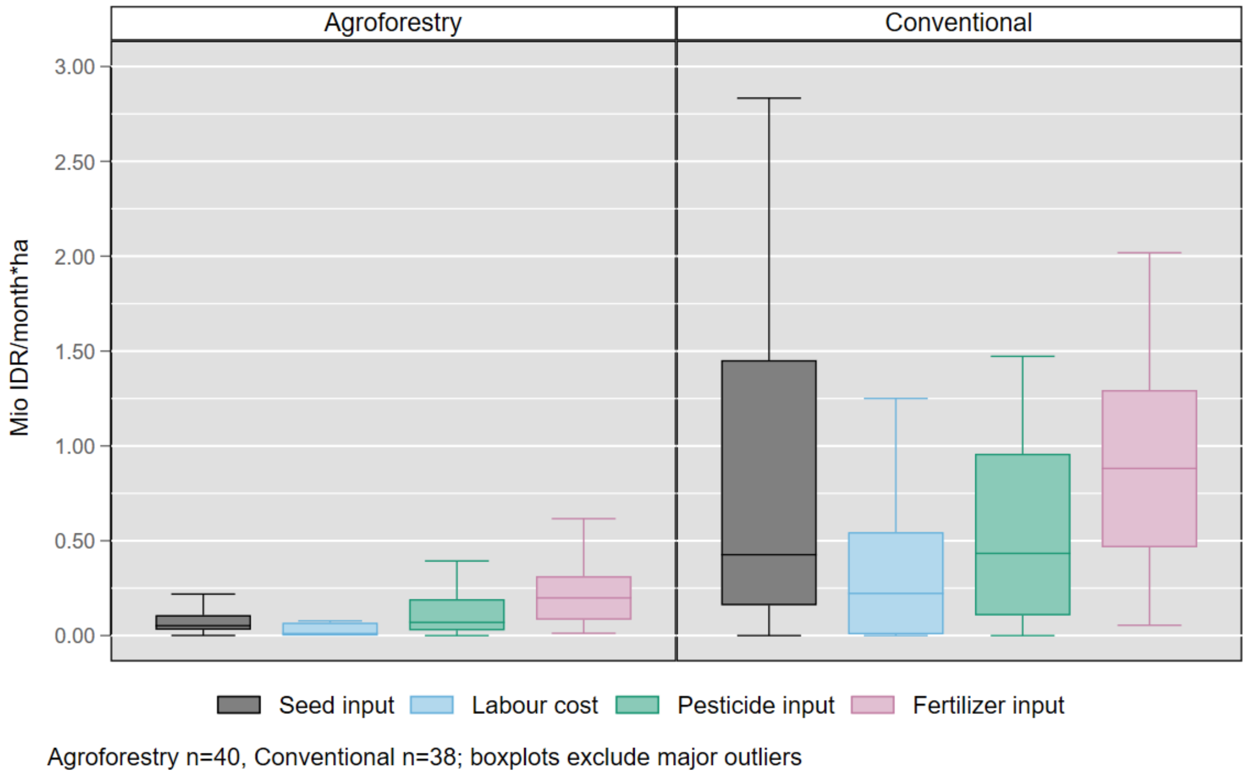

Figure 15: Monthly agricultural inputs per hectare in livelihood strategies (Mio IDR)

Seed input for both seasonal and perennial cropping was in *Agroforestry* with a median of 0.03 Mio IDR by 0.433 [0.179] Mio IDR (p<0.01) lower than in *Conventional* (1.87 Mio IDR, median 0.43 Mio IDR) where seed input was generally higher (Ranksum, U=292, P(AF>C)=0.192, p<0.01). On average households in *Agroforestry* spent 10% of their total seed investment on perennial crops, whereas in *Conventional* on average 100% was spent on seasonal crops. Labour input of family hours for both seasonal and perennial cropping was with median 493.50 hrs/year (14.47 hrs per capita and month) in *Agroforestry* by 618 hrs/year [272.935] (p<0.05) lower than the 1148.00 hrs/year (29.38 per capita and month) of *Conventional* (Ranksum, U=587, P(AF>C)=0.386, p<0.1). Similarly, median hired labour ratio (AF: 4%, C:31%) was by 33.81 pp [10.37] higher in *Conventional* (Ranksum, U=454, P(AF>C)=0.299, p<0.01). Thus, the investment into hired labour was multiple times higher in *Conventional* as compared to *Agroforestry*.

Median monthly fertilizer spending per hectare for seasonal and perennial cropping[9] was with 0.08 Mio IDR in *Agroforestry* by 0.703 [0.115] Mio IDR lower (p<0.01) than the 0.88 Mio IDR of Conventional (Ranksum, U=231, P(AF>C)=0.152, p<0.01). In the *Agroforestry* strategy the six most common types of fertilizer input were manure from cattle (55.17%), chicken manure (18.60%), MES (11.06%), Phonska (8.16%) and Urea (5.42%) and TSP (1.26%)). However, *Conventional* majorly resorted to MES (47.22%),

[9] Only few outliers existed that indicated specific expenditure for chemical fertilizer for perennial crops. Perennial crops profited mostly from inputs dedicated to seasonal crops which makes it reasonable to combine the input.

chicken manure (35.87%) and Phonska (8.23%), Urea (4.36%) and Convet (2.43%). Average and median monthly inputs in weight measure (stated for all three season) is provided in Table 14. Given the highly unequal distribution only Ranksum test results are provided.

Table 14: Monthly fertilizer input per hectare in seasonal cropping (kg)

	Agroforestry				Conventional				Ranksum-test of distrib.	
Type (kg)	mean	sd	p50	iqr	mean	sd	p50	iqr	U	P(AF>C)
Urea	13.892	18.293	6.332	21.503	11.951	19.079	0.000	20.000	614.5	0.596
TSP	3.664	12.952	0.000	0.000	9.952	22.164	0.000	1.818	689.5	0.454
Manure	286.335	445.520	142.536	345.156	0.000	0.000	0.000	0.000	209.0***	0.863
Phonska	154.415	858.504	15.764	22.430	91.717	159.752	40.755	75.547	665.0**	0.563
Convet	0.000	0.000	0.000	0.000	37.281	229.814	0.000	0.000	493.5***	0.325
Org. chicken manure	97.743	248.492	0.000	23.077	846.056	1791.534	0.000	615.385	613.5*	0.404
Org. MES	38.707	101.487	0.000	3.333	1167.659	2728.580	13.369	1000.000	422.0***	0.278

Agroforestry twice as cost-efficient but Conventional almost four times as profitable

Two measures were employed to understand farming efficiency and respective livelihood outcomes. First the benefit-cost ratio (BCR) was calculated as the ratio between the sum of revenues and sum of costs. This measure was applied to seasonal crops and seasonal and perennial crops combined.[10] Next, as measure for profitability the gross crop margin was calculated by the difference of revenues and costs divided by a measure of capital which in this case is the operated land area.

Figure 16 and Figure 17 provide an overview over Benefit Cost Ratios (BCR) and Gross Crop Profitability (GCP) margins. For A*groforestry* and *Conventional* the median latencies of the BCR for seasonal crops was 2.393 and 1.849 (Ranksum, U=639, P(AF>C)=0.580, p=0.226) respectively, with a negligible median difference (0.58 [0.722], t=0.81, p=0.419). Concurrently, for seasonal and perennial crops combined the median latency in the two strategies was 3.908 and 1.850 respectively (Ranksum, U=491, P(AF>C)=0.677, z=2.689, p<0.01) with a significant difference in medians of 1.997 [0.796] (p<0.05). In contrast, crop gross margin was substantially higher (Ranksum, U=499, P(AF>C)=0.328, p<0.01) in the *Conventional* group with a median latency of 4.942 Mio IDR per month as compared to Agroforestry (1.300 Mio IDR monthly). The median difference was large with 3.802 [1.753] Mio IDR monthly (Qreg_p50, t=2.17, p<0.05).

In conclusion, while there was no significant difference in the cost-efficiency for seasonal crop, *Agroforestry* was more than twice as cost-efficient when accounting for both seasonal and perennial crops. However, *Conventional* land use was on average almost four times more profitable than *Agroforestry*. Both measures do not account for livestock, fodder provided by crops and trees, and manure produced and used on the fields. However, total median farm BCR differed by about 2.46 [0.933] points (p<0.01) between *Conventional* (1.88) and *Agroforestry* (4.32). The probability of an *Agroforestry* smallholder having a higher BCR than a *Conventional* was high with 76.8% (Ranksum, U=353, p<0.01).

[10] Perennial crops, such as value trees, profit from input over several years. Often input that is applied to seasonal crops is applied to perennial crops as well. While this previous input is not included, the combination of seasonal and perennial crops corrects for windfall profits from harvesting value trees.

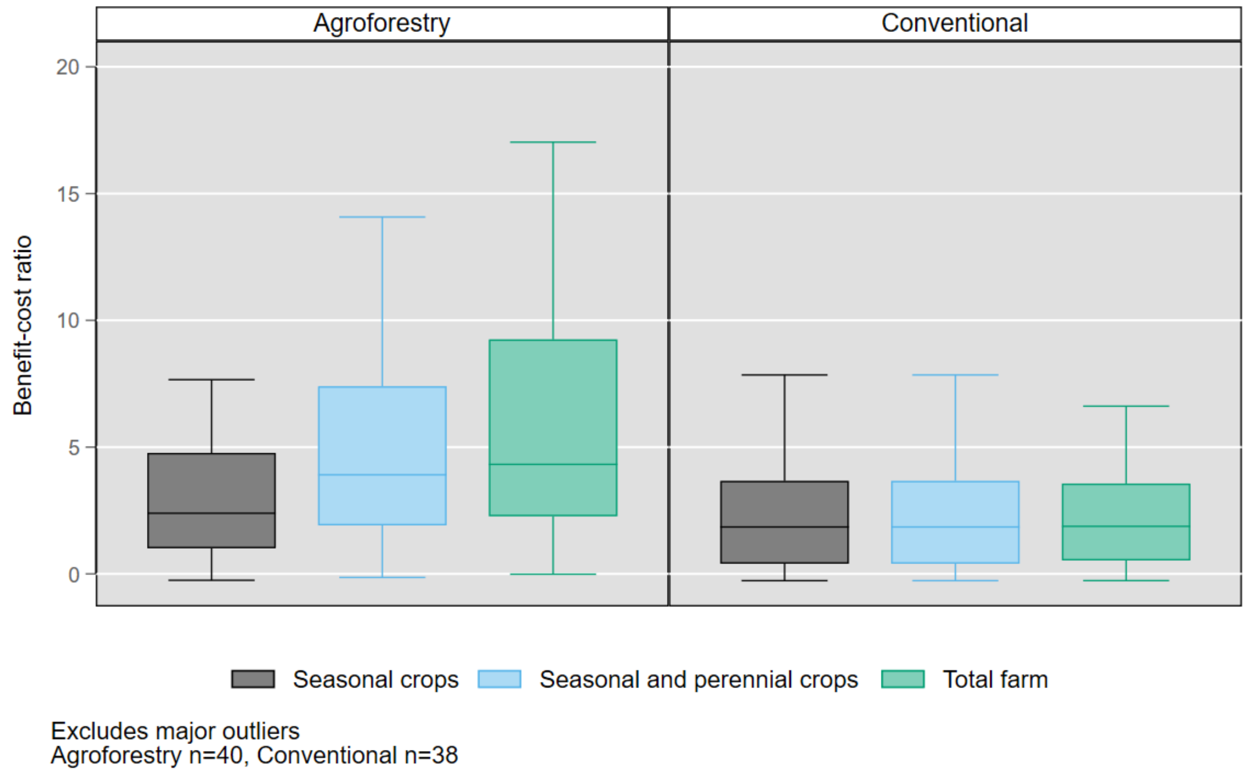

Figure 16: Benefit cost ratio of livelihood strategies

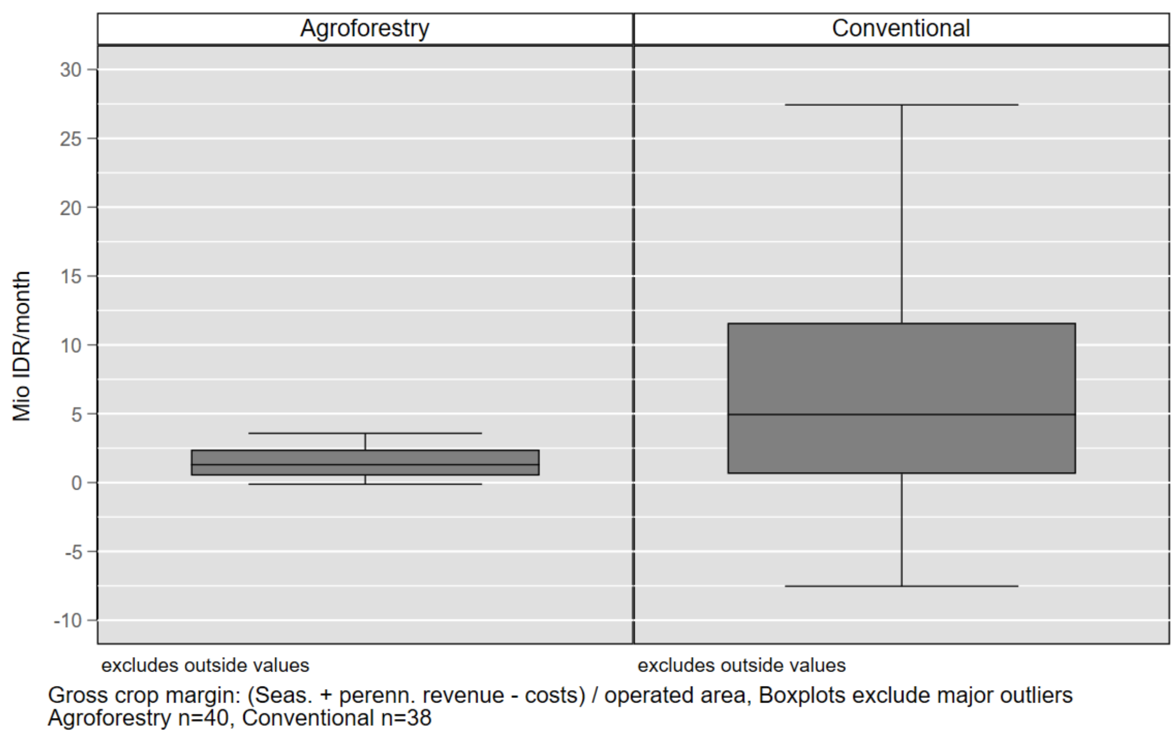

Figure 17: Seasonal and Perennial crop gross margin of livelihood strategies

The crops with the highest association with the BCR of seasonal and perennial crops were Maize (Kendall's τ_b=0.241, p<0.01), Tanaman Kalbi (Kendall's τ_b=0.240, p<0.01), Chilli (Kendall's τ_b=0.238, p<0.01), Coffee (Kendall's τ_b=0.230, p<0.01), Banana (Kendall's τ_b =0.1932 p<0.05).

While planting potatoes significantly reduced the BCR for seasonal and perennial crops (Kendall's τ_b =-0.142, p<0.1) it had the highest association with the Crop Gross Margin (Kendall's τ_b=0.410, p<0.01). Further, Crop Gross Margin rose with the cropping of carrots (Kendall's τ_b=0.225, p<0.05) and cabbage (Kendall's $\tau_b = 0.196$ at p<0.05) but sank with maize (Kendall's τ_b=-0.167 p<0.01.) and bamboo (Kendall's τ_b =-0.172, p<0.01).

5.2. Results-RQ2: Agroforestry significantly more resilient

This section answers RQ2 (*What is the level of resilience of the identified strategies?)* by presenting results from each resilience sub-dimension and closes with a synthesis in overall resilience and an effort to validate findings with subjective measures of resilience. Table 15, Table 16, Table 17, and Table 18 provide summary statistics and test results for sub-dimension and Tables B 17-19 in Appendix B for individual variables of the indicators. The construct validity of the indicator was assessed with McDonald's ω for the re-scaled variables. Buffer capacity had an observation to variable ratio of 78/29 (2.690) and an omega of 0.814. Capacity for self-organisation had an observation to variable ratio of 78/13 (6) and an omega of 0.509. For Capacity for learning and adaptation the observation the variable ratio was 78/21 (3.7), and for overall livelihood resilience it was 78/62 (1.2). In both cases, convergence could not be achieved by the algorithm, possibly due to the high number of binary variables and the low observation to variable ratio.

Figure 18 gives an overview on resilience scores across the different dimensions and farming system. All three dimensions of resilience as well as overall resilience was significantly more pronounced for the *Agroforestry* type. Table 15 gives a detailed overview of summary statistics, test results and details of statistical power for tests of the three dimensions and overall resilience. Mean livelihood resilience differed by 0.122 points between *Agroforestry* (0.595) and *Conventional* (0.474) groups (T-test, p<0.01). The two-sample mean test for livelihood resilience with unequal variances had a statistical power of 100% at all conventional significance levels, calculated for a Type II-error rate of 20%. In the sample, all three dimensions of resilience were reasonably associated with each other. The level of association between buffer capacity and capacity for learning and adaptation (Kendall's $\tau_b = 0.169$, p<0.05) and capacity for self-organisation (Kendall's $\tau_b = 0.228$, p<0.01) and between the latter two (Kendall's $\tau_b = 0.417$, p<0.01) suggested validity of construct and that all three dimensions measure coherently the overarching concept of resilience.

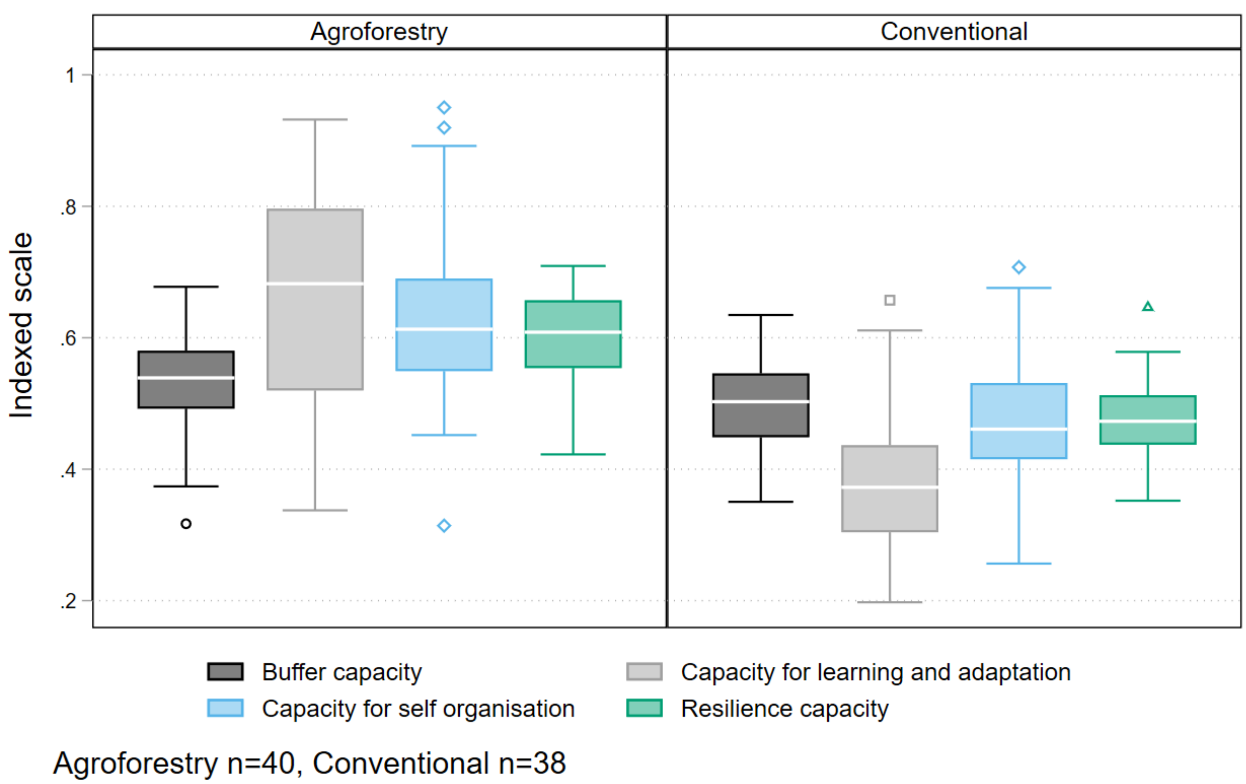

Figure 18: Resilience dimensions results

Overall, 12/16 (75%) of sub-dimensions, of which 3/6 in buffer capacity, 5/6 in capacity for learning and adaptation, and 4/4 in capacity for self-organisation scored significantly higher in the *Agroforestry* group indicating low compensability between them. On a lower refined level, only 27/62 (48.38%) individual variables, of which 12/28 variables of buffer capacity, 13/21 variables of capacity for learning and adaptation, and 5/13 variables of capacity for learning and adaptation had better outcomes in *Agroforestry.* To allow for comparison, all variables are detailed in Tables B 17-19 in Appendix B.

5.2.1. Buffer Capacity

The *Agroforestry* type scored significantly higher in 3 out of 6 sub-dimensions of buffer capacity. In the buffer capacity dimension of resilience *Agroforestry* (0.530) scored on average marginal 0.031 points higher than *Conventional* (0.503) (T-test, $p<0.01$). Figure 19 gives an overview on distributions of each sub-dimension and Table 16 (end of subsection) presents summary statistics and test results. Human capital did not differ significantly which is congruent with the similar distribution in the hamlets outlined in Table 9 and is therefore not more closely investigated. Subsequently major differences are explicated in detail and Table B 17 in Appendix B gives a detailed overview on summary statistics and test results.

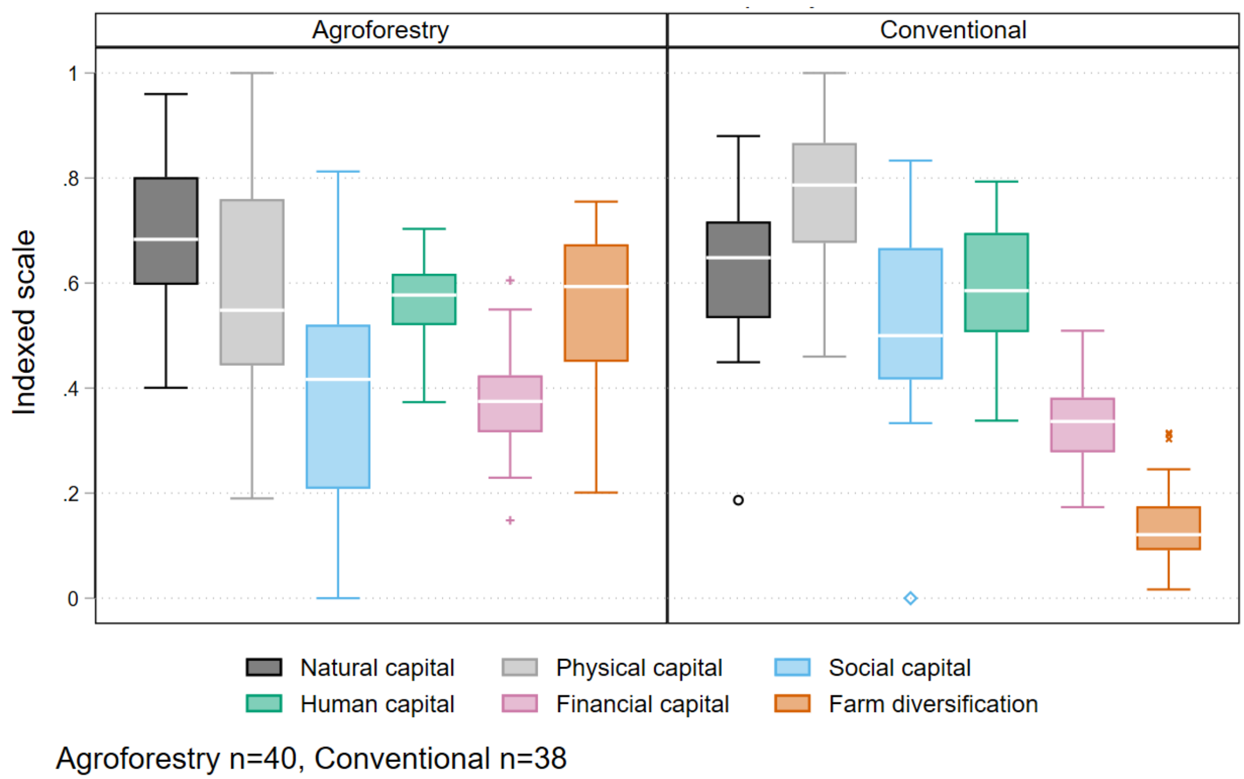

Figure 19: Buffer capacity - sub-dimension results

Natural capital

On average, *Agroforestry* (0.698) scored a marginal 0.064 points higher than *Conventional* (0.633) (T-test, $p<0.05$). In the whole sample, 5 households did not own any land but rented plots, all of which followed the *Conventional* strategy. Soil conditions were assessed in several ways. First, an almost identical proportion of land was on slopes (51 %) in both groups. Next, farmers were similarly worried about the future of their farm because of soil related problems (median of 2, Likert-scale 1=best - 6=worst). Third, farmers rated the soil for easiness of ploughing in the *Agroforestry* group with 1.65 and *Conventional* with 1.76. Reported overall number of soil related problems did not differ significantly between smallholders in the *Agroforestry* group and *Conventional* group, but the former reported more twice as many problems with soil erosion and soil conditions during the dry season (see Figure 20). "Dryness", without closer specification, was often mentioned as "Other" and therefore accounted for separately. In the *Conventional* group 9 more smallholders (11.5% of the sample) reported unfertile soils than in the *Agroforestry* group.

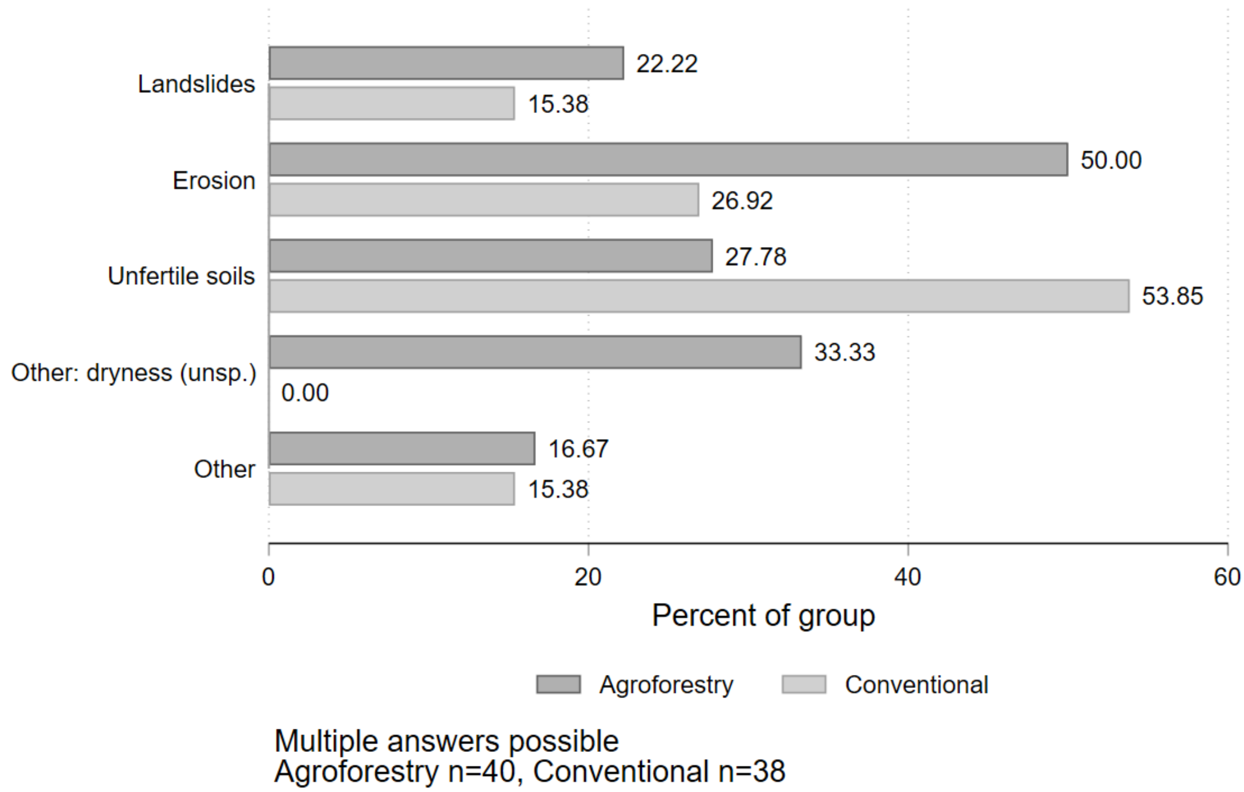

Figure 20: Major soil related problems

Physical capital

On average the *Agroforestry* type (0.604) scored 0.17 points lower than the *Conventional* type (0.777) (T-test, p<0.05) in physical capital. Connection to infrastructure (e.g. schools, hospitals, market, trader) was reported as being equally good, but road conditions during the wet season were significantly better for the *Agroforestry* type (median 1) than the *Conventional* type (median 2) (Median-test, p<0.1 and Ranksum-test, p<0.1). Average access to irrigation water was significantly less for *Agroforestry* households (67.5%) than for *Conventional* (94.7%) (Proportion-test, p<0.01). The difference was even more pronounced for household water, where on average 47.36 pp more households in the *Agroforestry* sub-group reported easy access (Proportion-test, p<0.01). Last, the *Conventional* type reported using significantly more technically advanced irrigation systems, e.g. pumps and pipes, than *Agroforestry* sub-group (T-test, p<0.01).

Social capital

On average, the *Agroforestry* type (0.378) scored by 0.136 points lower than the *Conventional* type (0.515) (T-test, p<0.01) in social capital. First, respondents were asked which kind of support they received from community groups during crises, and answers were surprisingly balanced between the two types (Figure 21).

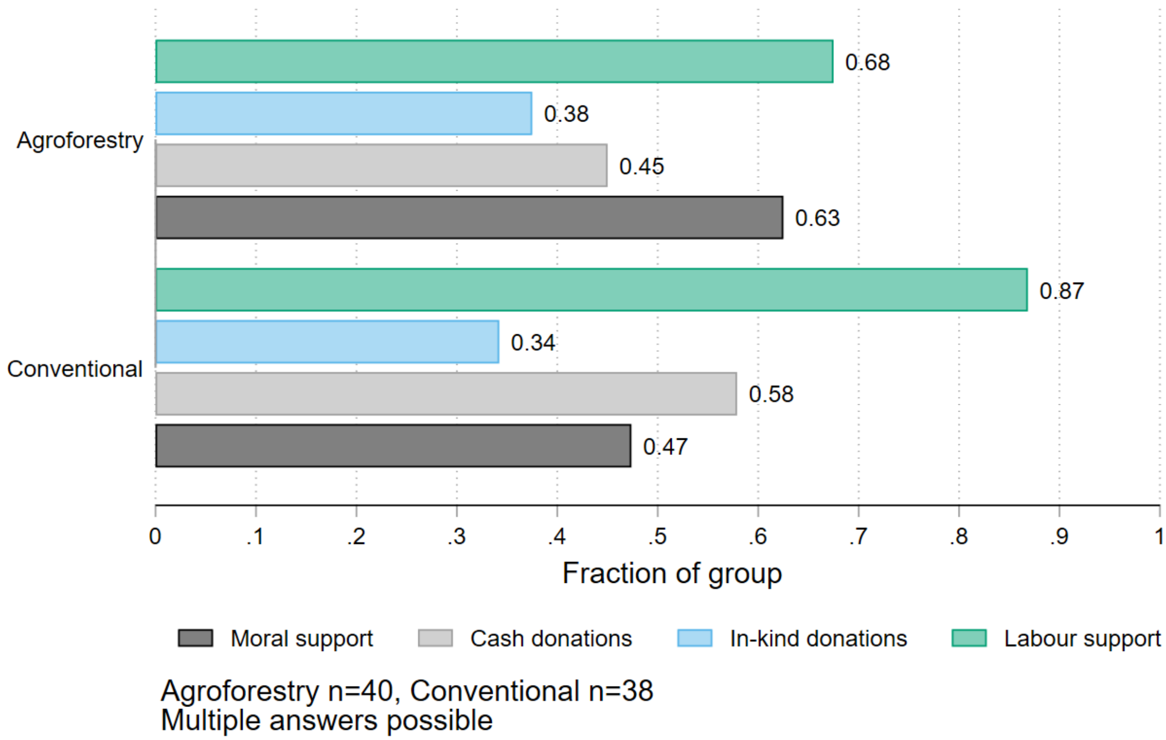

Figure 21: Community group support

Overall group membership in *Conventional* was with 1.89 groups on average per household almost twice as high as in *Agroforestry* (T-test, p<0.01), suggesting stronger formal institutionalisation in the Penanggungan II hamlet. The most frequent groups attended were savings and women groups, as well as religious groups. Last, the average participation for community groups was ascertained, and while no differences in medians (both 1) could be found the results of the Ranksum-test (U=505.5, P(AF>C)=0.333, p<0.01) suggest that the difference in means (*Agroforestry* 68.2%, *Conventional* 95.4%) between the group is valid and *Conventional* group participants were more active in institutional social life.

Financial capital

The *Conventional* group (0.333) scored by on average 0.041 points significantly lower than the *Agroforestry* group (0.374) (T-test, p<0.05). First, in both groups more than 90% reported access to informal credits. And whereas in the *Agroforestry* (47.22%) 14.94 pp less households reported access to formal credit than in the *Conventional* group, no significant difference could be found. No significant differences between landholdings in *Agroforestry* (0.793 ha) and *Conventional* (0.824 ha) groups could be ascertained. Farmers in the *Conventional* group (median 0 TLU) had significantly less livestock than the *Agroforestry* group (median 0.715) (Ranksum-test, U=245, P(AF>C)=0.839, p<0.01). Whilst the overall amount of equipment between the types did not differ significantly, in the *Conventional* group more than twice as many mechanical pesticide applicators, irrigation pumps and pipe infrastructures were used. On the other hand, the *Agroforestry* smallholders used more manual equipment (e.g. hoes, harrows, manual pesticide applicators and *kayuls,* manual tools for working the land), which corroborates the distinction between farming styles. Income diversity was assessed by using the inversed Simpson's Diversity Index and was distinctly more pronounced in the *Agroforestry* group (median 1.040) compared to the *Conventional* group (median 0.615) (Ranksum-test, U=385, P(AF>C)=0.747, p<0.01). No significant difference in mean (1.468 and 2.191 Mio IDR) and median (1.093 and 1.229 Mio IDR) monthly per capita income for *Agroforestry* and *Conventional* respectively could be ascertained.

Farm diversification

Generally, farms were significantly more diversified in *Agroforestry* type (median 0.564) than in *Conventional* (median 0.121) (Ranksum-test, U=11, P(AF>C)=0.993, p<0.01). Median crop diversity as assessed by the inversed Simpson's Diversity Index based on value of harvests was distinctly larger in *Agroforestry* (2.895) than in *Conventional* (1.340) (Ranksum-test, U=181, P(AF>C)=0.881, p<0.01). Smallholders applying the *Agroforestry* system planted with a median of 8 plant varieties twice as many than their *Conventional* counterparts during the past year (Ranksum-test, U=244,P(AF>C)=0.839, p<0.01). Similarly, large differences in livestock diversity between the respective groups existed. By using the inversed Simpson's Diversity Index based on TLU and herd size (all animals) it was ascertained that the *Agroforestry* system was on average by a factor of 10 more diversified (Ranksum-test, U=190.5, P(AF>C)=0.875, p<0.01). Finally, the share of operated land under *Agroforestry* was significantly higher in the *Agroforestry* system (mean 68.5%, median 100%) than in the *Conventional* system (mean 1.7% median 0%) (Ranksum-test, U=0, P(AF>C)=1, p<0.01).

Overall, several variables hint at a more intense and specialized farming system of the *Conventional* group, where unfertile soil prevailed. However, under the assumption of diversity increasing resilience the households in the *Agroforestry* system have a distinctly higher buffer capacity thus allowing them to encounter shocks and hazards better than the *Conventional* system.

Table 15: Resilience and dimensions - test results

Resilience	Agroforestry				Conventional				Student's t-test			Ranksum-test of distrib.			Quantile regression at median		
	mean	sd	p50	iqr	mean	sd	p50	iqr	Mean-diff.		Std. Err.	U	P(AF>C)		Median-diff.		Std. Err.
Buffer capacity	0.530	0.070	0.539	0.088	0.499	0.060	0.503	0.097	0.031	**	0.015						
Capacity for learning and adaptation	0.659	0.155	0.682	0.277	0.379	0.107	0.372	0.132				101.0	0.934	***	-0.306	***	0.053
Capacity for self-organisation	0.628	0.126	0.613	0.141	0.475	0.103	0.461	0.116	0.153	***	0.026						
Resilience capacity	0.595	0.072	0.608	0.103	0.474	0.062	0.473	0.075	0.122	***	0.015						

Note: ** p < 0.1, ** p < 0.05, *** p < 0.01; Statistical power of Student's t-test (power= 0.8, beta=0.2) at alpha=(0.1|0.05|0.01): Buffer capacity=(0.669 | 0.546 | 0.320), Capacity for self-organisation=(1.000|0.999|0.999), Resilience=(1.00)*

Table 16: Buffer capacity sub-dimensions - test results

	Agroforestry				Conventional				Student's t-test			Ranksum-test of distrib.			Quantile regression at p_50		
Buffer capacity	mean	sd	p50	iqr	mean	sd	p50	iqr	Mean-diff.		Std. Err.	U	P(AF>C)		Median-diff.		Std. Err.
Natural capital	0.698	0.149	0.683	0.205	0.633	0.128	0.648	0.184	0.064	**	0.032						
Physical capital	0.604	0.217	0.548	0.317	0.777	0.150	0.787	0.190	-0.173	**	0.042						
Social capital	0.378	0.205	0.417	0.313	0.515	0.170	0.500	0.250	-0.136	***	0.043						
Human capital	0.571	0.080	0.577	0.098	0.595	0.115	0.586	0.189	-0.025		0.023						
Financial capital	0.374	0.091	0.375	0.108	0.333	0.082	0.337	0.104	0.041	**	0.020						
Farm diversification	0.564	0.142	0.593	0.224	0.144	0.075	0.121	0.084				11.0	0.993	***	-0.453	***	0.039
Buffer capacity	0.530	0.070	0.539	0.088	0.499	0.060	0.503	0.097	0.031	**	0.015						

Note: ** p < 0.1, ** p < 0.05, *** p < 0.01*

5.2.2. Capacity for learning and adaptation higher in Agroforestry

Capacity for learning and adaptation was almost twice as high for *Agroforestry* (0.682) compared to *Conventional* (0.372) (Ranksum-test, U=101, P(AF>C)=0.934, p<0.01). Figure 22 gives an overview on distributions of each sub-dimension and Table 17 presents summary statistics and test results (end of sub-section). Openness to change did not differ significantly and is therefore not more closely investigated. All other sub-dimensions were significantly more pronounced in the *Agroforestry* group. Subsequently major differences are explicated in detail.

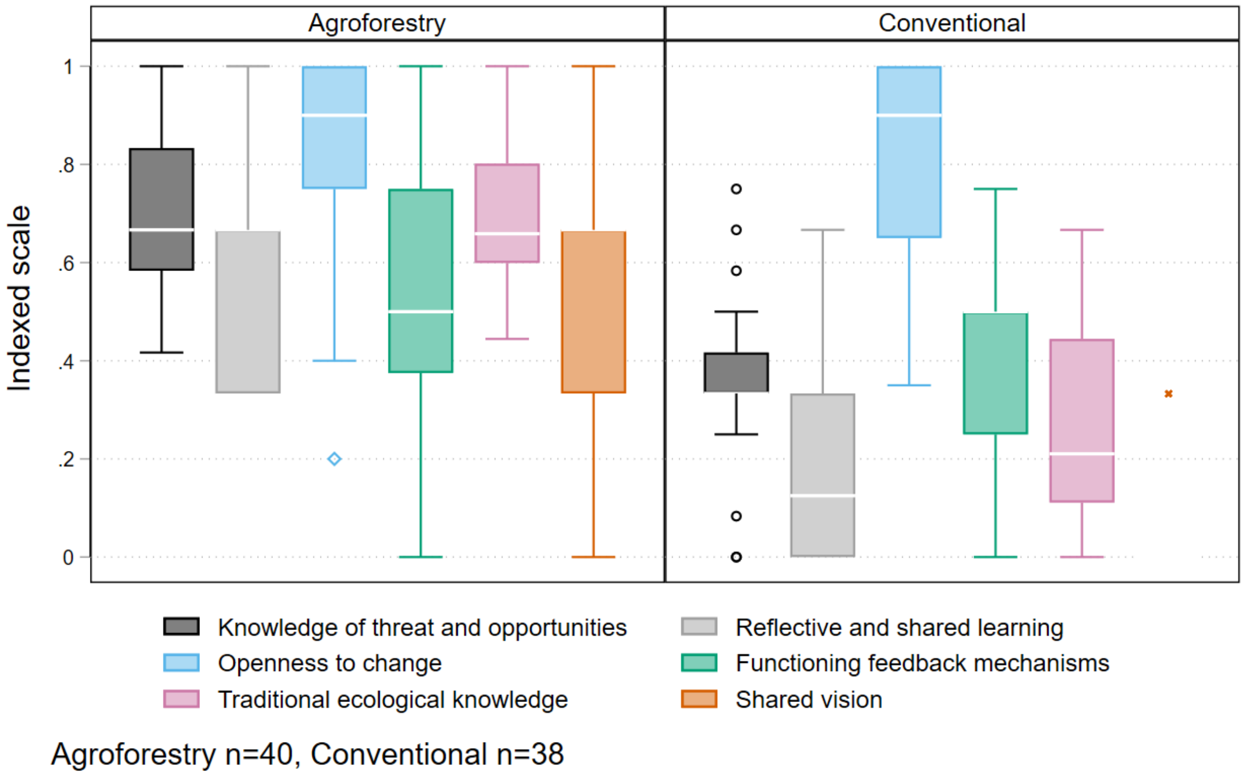

Figure 22: Capacity for learning and adaptation sub-dimensions results

Knowledge of threat and opportunities

Knowledge of threat and opportunities intends to indicate the anticipatory capacity of households towards hazards and shocks. It was almost twice as high for *Agroforestry* (0.7) compared to *Conventional* (0.366) (Ranksum-test, U=78, P(AF>C)=0.949, p<0.01). In this sub-dimension, the major difference between the groups may be explained by the presence of agricultural extension services in the hamlets of Wanasari/Tamansari and its absence in Penanggungan II. Next, whereas 52.5% of smallholders in the *Agroforestry* group participated in governmental programmes (mostly Integrated Pest Management Schools, trainings on farming techniques and community disaster response) the proportion was less by 44.61 pp in the *Conventional* group (Proportion test, p<0.01). No significant differences in awareness of potential hazards or shocks existed between the groups, nor in respective coping mechanisms (see the subsequent chapter).

Reflective and Shared Learning

The reflective and shared learning sub-dimensions indicate the household's ability to reflect on livelihood strategies and share learnings with neighbours. On average the sub-dimension was by 0.327 points higher for *Agroforestry* (0.557) compared to *Conventional* (0.229) (T-test, p<0.01). The first variable considered trainings provided by community groups and participation was by 21.05 pp higher in the *Agroforestry* group (Proportion-test, p<0.1). Concurrently, 14.61 pp more smallholders in *Agroforestry* (22.5%) compared to *Conventional* indicated learning from neighbours (Proportion-test, p<0.1). Participation in the local farmers group was by 62.57 pp on average higher in *Agroforestry* (94.57%) than in *Conventional* (32%) (T-test, p<0.01).

Openness to change

Openness to change indicates if the household changed farming strategies recently according to different stimuli. In both groups more than a third of smallholders indicated changing farm strategies due to technology change or consumer demands recently. Similarly, both groups answered the question about awareness of knowledge gaps in farming on average with 1.5 (Likert, 1=agree to 6=disagree). Self-assessment of openness to change did not diverge significantly between groups and centred around 1.5 as well (Likert, 1=agree to 6=disagree). Overall, the sub-dimension did not differ significantly between the identified livelihood strategies.

Functioning feedback mechanisms

The functioning feedback mechanisms sub-dimension seeks to investigate systems that support smallholders. *Agroforestry* (0.594) scored on average by 0.173 points higher than *Conventional* (0.421) (T-test, p<0.01). The share of smallholders receiving governmental subsidies was on average twice as high in *Agroforestry* (65%) than in *Conventional* (36.84%) (Proportion-test, p<0.05). The attendance of Integrated Pest Management (IPM) trainings was considered as a fitting variable for this sub-category, as pesticide input is exceptionally high on average in the region. Whereas in *Agroforestry* nearly half of the group participated only 10% of the *Conventional* group participated in an IPM (Proportion-test, p<0.01). Similarly, 47.5% of household-heads in the *Agroforestry* group had social security as compared to 28.94% of *Conventional* (Proportion-test, p<0.1). Last, no significant difference in expected community support during crises could be ascertained.

Existence and use of local traditional knowledge

The median difference in existence and use of local traditional knowledge score between the *Agroforestry* system (0.688) and *Conventional* (0.268) was 0.436 points (p<0.01, and Ranksum-test, U=78, P(AF>C)=0.949, p<0.01). Present soil management practices were arbitrarily considered as local and traditional knowledge given that qualitative evidence during interviews suggested that both areas underwent several major changes in their farming methods in the last 30-50 years. On average, *Agroforestry* applied two more strategies than *Conventional* (T-test, p<0.01). Figure 23 shows the applied techniques. As productive agricultural system and as soil management strategy, agroforestry in the above sense was considered as local and traditional knowledge. On average only 23.68% of *Conventional* smallholders applied agroforestry the strategy. Mostly, a small number of trees surrounding plots to prevent runoff and erosion were indicated. Finally, the number of meals a week without rice were considered as traditional and local (altitude and climatic parameters prevent rice farming). Out of 21 meals a week, on average about 6.775 for *Agroforestry* and 3.263 for *Conventional* smallholders were meals without rice (Ranksum-test, U=558.5, z=2.135, p<0.05).

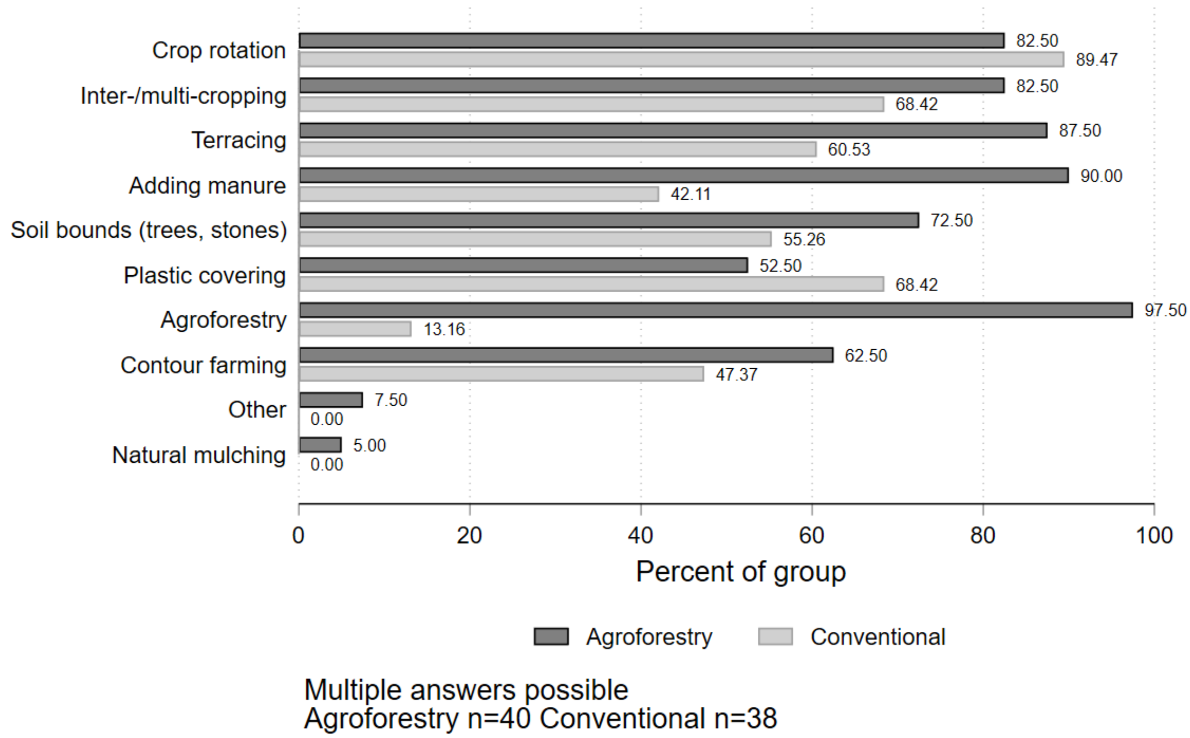

Figure 23: Soil and water conservation techniques

Shared vision more pronounced in Agroforestry

A shared vision is an intangible asset that is theorized to help accelerate individual efforts in bringing about a positive change in the community. Here, it redundantly considers variables employed in other sub-dimensions and is conceptualized as different perspective on the very same variables. The sub-dimension was well pronounced in *Agroforestry* group (median 0.667) and practically non-existent in the *Conventional* group (Ranksum-test, U=95, P(AF>C)=0.938, p<0.01). Test-results for extension service presence, participation in government programmes, and learning from neighbours can be obtained from above.

5.2.3. Capacity for self-organisation significantly higher for *Agroforestry* type

Agroforestry (0.628) scored with on average 0.153 points higher in the capacity for self-organisation than *Conventional* (0.475) (T-test, p<0.01). Figure 24 gives an overview on distributions of each sub-dimension and Table 18 presents summary statistics and test results. All sub-dimensions were significantly more pronounced in the *Agroforestry* group. Subsequently major differences are explicated in detail. Table B 19 in Appendix B gives an overview on summary statistics and test results of individual variables.

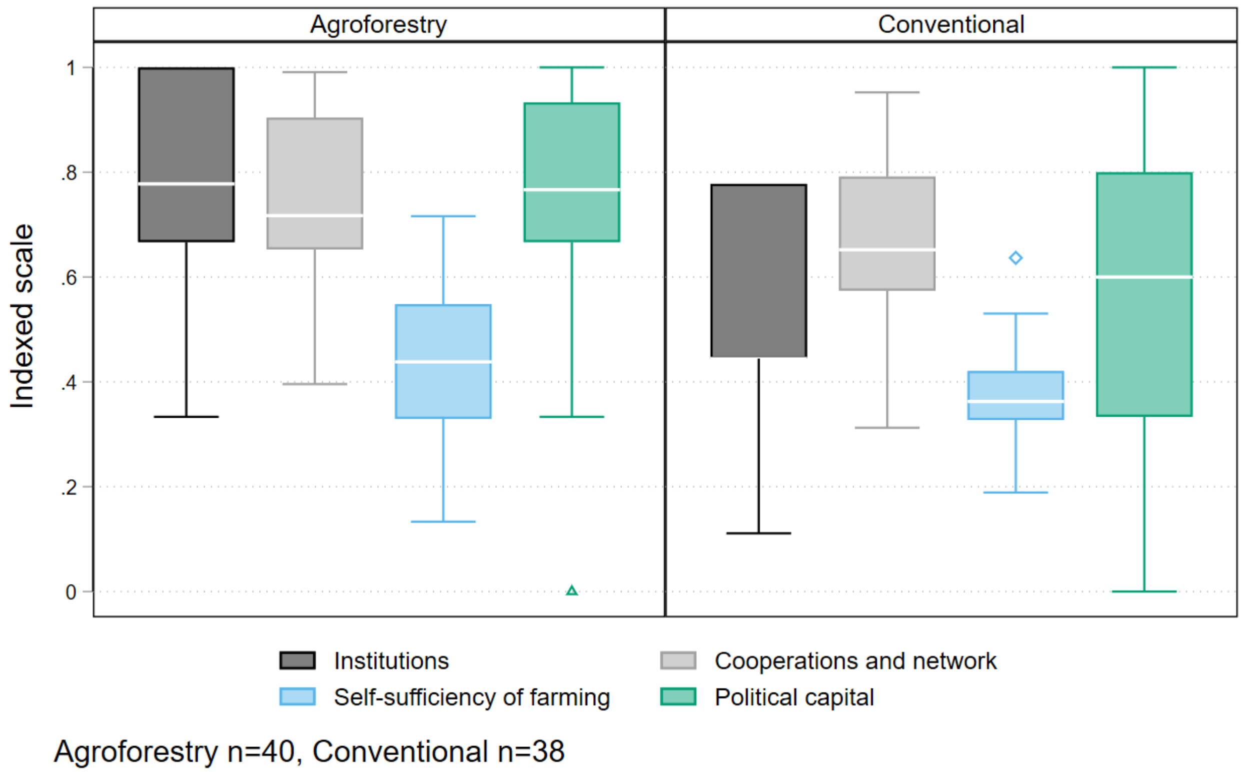

Figure 24: Capacity for self-organisation sub-dimensions results

Institutions significantly more developed in Agroforestry

Institutions essentially are intended to depict relations of smallholders and their community groups and how these enable them to achieve better livelihood outcomes. *Agroforestry* (median 0.778) was significantly more pronounced than *Conventional* (0.444) in institutions (Ranksum-test, U=528, P(AF>C)=0.795, p<0.01). For example, the ordinal variable of marketing, assessed marketing power of smallholders by asking if they sell their produce i) in direct contract (no middlemen) as individuals, ii) to traders (middlemen) as individuals, and both options as farmers group iii) and iv) (Figure 25). Marketing power was only slightly higher in *Agroforestry* (median 2) compared to *Conventional* (median 2) (Ranksum-test, U=460, P(AF>C)=0.697, p<0.01).

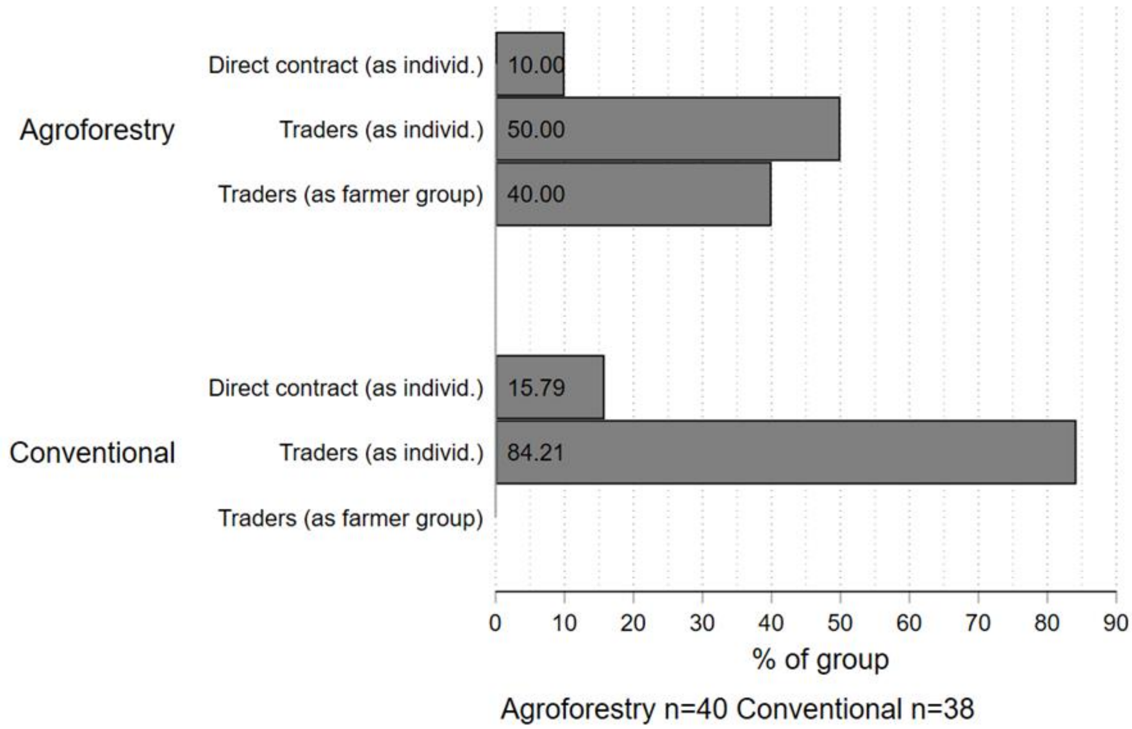

Figure 25: Marketing strategies

However, a significant higher proportion of on average 14.60 pp of smallholders in *Conventional* farming (92.11%) were able to negotiate the price with buyers as compared to *Agroforestry* (77.5%) (Proportion-test, $p<0.1$). Last, 100% of smallholders of the *Agroforestry* type are part of a farmers group as compared to 42.10% of smallholders in *Conventional* (Proportion-test, $p<0.01$).

Cooperation and network significantly more developed in Agroforestry

The sub-dimension shows inter-group cooperation that can alternatively also be assigned to social capital. However, the proposed agro-ecological resilience indicator offers a more detailed differentiation that helps to take a closer look at sub-dimensions critical in times of disasters. Generally, the *Agroforestry* group (median 0.717) scored marginally higher in the sub-dimension than *Conventional* (median 0.652) (Ranksum-test, U=528, P(AF>C)=0.652, $p<0.05$), with no significant difference in medians. In both groups '*trust in other community members in terms of borrowing and lending cash'* was equally high and centred around the highest to the second highest Likert scale items (full trust to very trustful). Likewise, '*savings/investment group participation'* was with 95% very high in both groups. However, these characteristics seemed to be expressed differently in each group. The median of the ordinally measured '*Reciprocity: ratio of borrowing:lending (yearly)'* for *Agroforesty* was 0.6 (Ranksum-test, U=577, P(AF>C)=0.380, $p<0.1$). On the contrary, '*Reciprocity: ratio of receive-give (monthly)'* had the same median of 1 in both groups and distributions did not differ significantly.

Self-sufficiency significantly more developed in Agroforestry

Self-sufficiency is an important aspect of household resilience, as it shows the ability to cope with market shocks or natural hazards. *Agroforestry* type (0.438) had on average by 0.072 points (Median-diff., $p<0.1$) significantly higher self-sufficiency than the *Conventional* type (0.377) (Ranksum-test, U=562.5, P(AF>C)=0.630, $p<0.05$). Home-garden size did not differ significantly between the groups with a sample mean of 184.68 m^2. However, self-consumption of total farm production was estimated with 49.2%

(median=50%) in the *Agroforestry* with 35% higher (Median-diff., p<0.05) as compared to 17.37% (median=12.5%) in the *Conventional* group (Ranksum-test, U=313, P(AF>C)=0.794 , p<0.01). Farm income sufficiency (Likert, 1=agree to 6=disagree) was rated in both groups at median 2, with the mean rank of *Conventional* being significantly lower (Ranksum-test, U=460.5, P(AF>C)=0.697, p<0.01)

Political capital significantly more developed in Agroforestry

Political capital was significantly more developed in *Agroforestry* (median 0.767) as compared to *Conventional* (median = 0.600) (Ranksum-test, U=478, P(AF>C)=0.686, p<0.01). Political capital was assessed in the protocol with the question *"When you have an idea to change something in your community, to whom would you likely go?"* with the possibility to rate Neighbours/friends and relatives, community leaders, and community group meetings separately (Likert, 1=most likely to 6=least likely). The first option was rated on average with median of 1 and did not differ significantly between groups. Community leaders had a likelihood of 36.3% to be better rated in *Agroforestry* (median = 1) than in the *Conventional* group (median=6) (Ranksum-test, U=568.5, P(AF>C)=0.384, p<0.01), which suggests higher trust in community leaders in the former group. Community group meetings had equal median ratings of 1 in both groups, but the probability was 40.82% of observations being rated higher in the *Agroforestry* group compared to the *Conventional* group (Ranksum, U=598, p<0.01).

Table 17: Capacity for learning and adaptation sub-dimension statistics and test results

Capacity for learning and adaptation	Agroforestry				Conventional				Student's t-test			Ranksum-test of distrib.			Quantile regression at p_50		
	mean	sd	p50	iqr	mean	sd	p50	iqr	Mean-diff.		Std. Err.	U	P(AF>C)		Median-diff.		Std. Err.
Knowledge of threats and opportunities	0.700	0.165	0.667	0.250	0.366	0.143	0.333	0.083				78.0	0.949	***	-0.333	***	0.041
Reflective and shared learning	0.557	0.231	0.667	0.333	0.229	0.260	0.125	0.333	0.327	***	0.056						
Openness to change	0.820	0.212	0.900	0.250	0.779	0.231	0.900	0.350				705.0	0.536		0.000		0.049
Functioning feedback mechanism	0.594	0.298	0.500	0.375	0.421	0.175	0.500	0.250	0.173	***	0.055						
Traditional ecological knowledge	0.688	0.136	0.659	0.202	0.268	0.191	0.210	0.333				73.5	0.952	***	-0.437	***	0.056
Shared vision	0.550	0.257	0.667	0.333	0.070	0.138	0.000	0.000				95.0	0.938	***	0.000		
Capacity for learning and adaptation	0.659	0.155	0.682	0.277	0.379	0.107	0.372	0.132				101.0	0.934	***	-0.306	***	0.053

Note: ** p < 0.1, ** p < 0.05, *** p < 0.01*

Table 18: Capacity for self-organisation sub-dimension statistics and test-results

Capacity for self-organisation	Agroforestry				Conventional				Student's t-test			Ranksum-test of distrib.			Quantile regression at median		
	mean	sd	p50	iqr	mean	sd	p50	iqr	Mean-diff.		Std. Err.	U	P(AF>C)		Median-diff.		Std. Err.
Institutions	0.781	0.184	0.778	0.333	0.541	0.188	0.444	0.333				312.0	0.795	***	-0.333	***	0.054
Cooperation and network	0.742	0.157	0.717	0.251	0.664	0.162	0.652	0.218				528.5	0.652	**	-0.071		0.048
Self-sufficiency	0.438	0.151	0.438	0.219	0.377	0.084	0.363	0.094				562.5	0.630	**	-0.072	*	0.039
Political capital	0.733	0.243	0.767	0.267	0.558	0.288	0.600	0.467				478.0	0.680	***	-0.133		0.116
Capacity for self-organisation	0.628	0.126	0.613	0.141	0.475	0.103	0.461	0.116	0.153	***	0.026						

Note: ** p < 0.1, ** p < 0.05, *** p < 0.01*

5.2.4. Results-RQ2-SQ1: Buffer capacity validated by stated wellbeing and resilience

To validate the consistency of the overall resilience construct, measures of association between subdimensions were obtained as described in the beginning of Chapter 6.2. Further, to validate the calculated resilience score with direct measures of stated wellbeing and resilience, the protocol explicitly asked the respondents to rate their wellbeing in comparison to hamlet neighbours[11] and their household resilience[12] in the light of a future hazard or shock. For both, stated wellbeing (1-6=best) and stated resilience (1-10=best) the two strategies had equal medians of 4 and 8 respectively in the two strategies. Both variables and summary statistics and test results are provided in Table 19.

Table 19: Stated resilience and wellbeing

	Agroforestry				Conventional				Ranksum-test of distributions	
	mean	sd	p50	iqr	mean	sd	p50	iqr	U	P(AF>C)
Stated resilience [1-10=best]	7.744	2.009	8	4	7.459	2.049	8	3	656.0	0.545
Stated wellbeing [1-6=best]	3.875	0.883	4	1	4.026	0.854	4	0	627.0	0.412

The two stated measures are weakly but significantly associated (Kendall's $\tau_b = 0.193$, p<0.05), and no significant differences in stated resilience or wellbeing between the strategies existed. Figure 26 gives a bi-variate overview on the relationship between the two stated measures in the subgroups and the sample (Total).

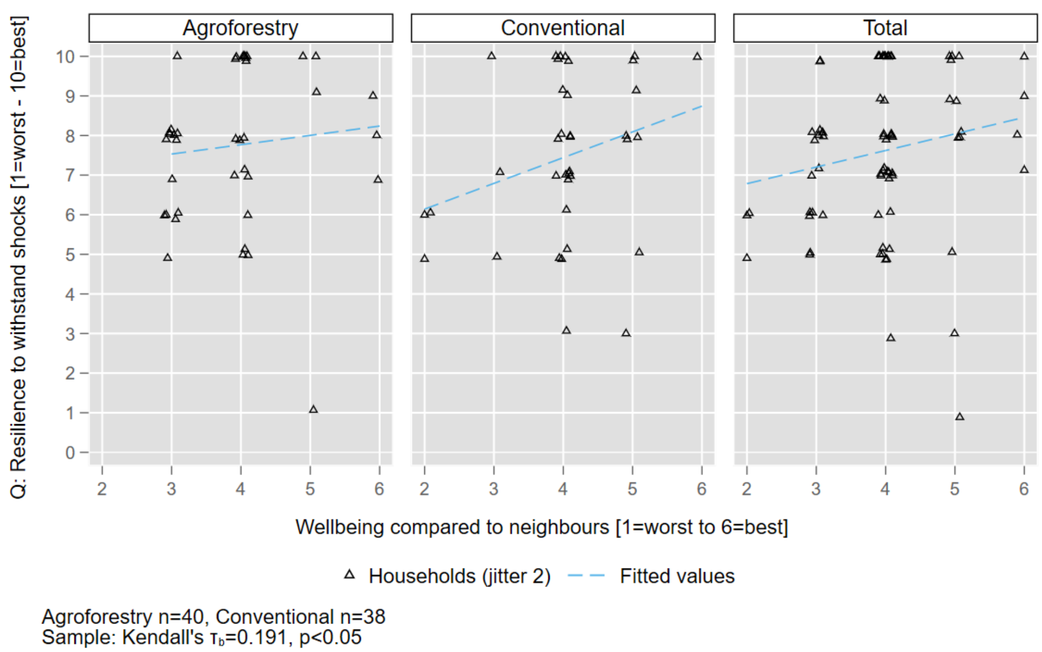

Figure 26: Stated resilience and wellbeing

[11] F5. *How do you rate your current overall living conditions and wellbeing compared to the average household in your community?* [1= much worse to 6=much better], scale reversed for correlations and graphing.
[12] F4: *How high do you think is the capability of your household to withstand future hazard or shock?* [1=very weak to 10=very strong], scale reversed for correlations and graphing.

Stated wellbeing and calculated resilience associated at sample level

Measures of association for stated survey items and calculated scores are provided in Table B 20, Appendix B. Regarding the stated measures of wellbeing and resilience, in the sample the positive albeit weak association (Kendall's $\tau_b = 0.193$, p<0.05) suggests that the related concepts are valid and weakly related. Similarly, the variables were associated in the *Conventional* group (Kendall's $\tau_b = 0.243$, p<0.1), but not in the *Agroforestry* group. However, amongst all three dimensions, only buffer capacity was associated with wellbeing (Kendall's $\tau_b = 0.293$, p<0.05) in the sample.

Given these inconclusive association results, and that the question of resilience (*"household's ability to withstand a shock"*) is, i) quite abstract, ii) was challenging to translate into Javanese/Bahasa Indonesia, and iii) seemed difficult to answer for respondents during the survey, wellbeing is regarded as more valid measure for comparison. Further, examples in literature use wellbeing as comparison measure.

Next, the sample and the two groups of households were tested separately for their association between the calculated resilience score and wellbeing and stated resilience, respectively. The *Agroforestry's* sub-group calculated resilience score was moderately positively associated with wellbeing (Kendall's $\tau_b = 0.293$, p<0.05), but not with stated resilience. No significant association between the survey variables and the calculated score exists in the *Conventional* group.

The sample's stated wellbeing was weakly associated with the calculated buffer capacity of resilience (Kendall's $\tau_b = 0.203$, p<0.05). No other significant association existed between variables at sample level. In the *Agroforestry* group, wellbeing was closely associated with buffer capacity (Kendall's $\tau_b = 0.446$, p<0.01) and capacity for self-organisation (Kendall's $\tau_b = 0.376$, p<0.01). However, stated resilience was associated with capacity for learning and adaptation in the *Agroforestry* group (Kendall's $\tau_b = -0.262$, p<0.05) and capacity for self-organisation in the *Conventional* group (Kendall's $\tau_b = 0.243$, p<0.1). The latter two associations were deemed inconsequential given the more promising validity of stated wellbeing.

In conclusion, the calculated resilience score is internally valid and reasonably associated with wellbeing, possibly implying that relative wellbeing carries more meaning for respondents than concepts of resilience. Of all three dimensions, the validation via association with wellbeing shows only consistent results for buffer capacity, while results for the other two subdimension remain inconclusive, as their correlations have indeed the right direction (positive association throughout), but are rather weak, and not statistically different from zero at any conventional significant level.

5.3. RQ3: Shocks and coping strategies

Resilience measurement requires the assessment of prominent shocks the households experienced and respective applied coping strategies. Respondents were asked about the most impactful shock in the last 5 years and respective coping strategies (see Figure 27).

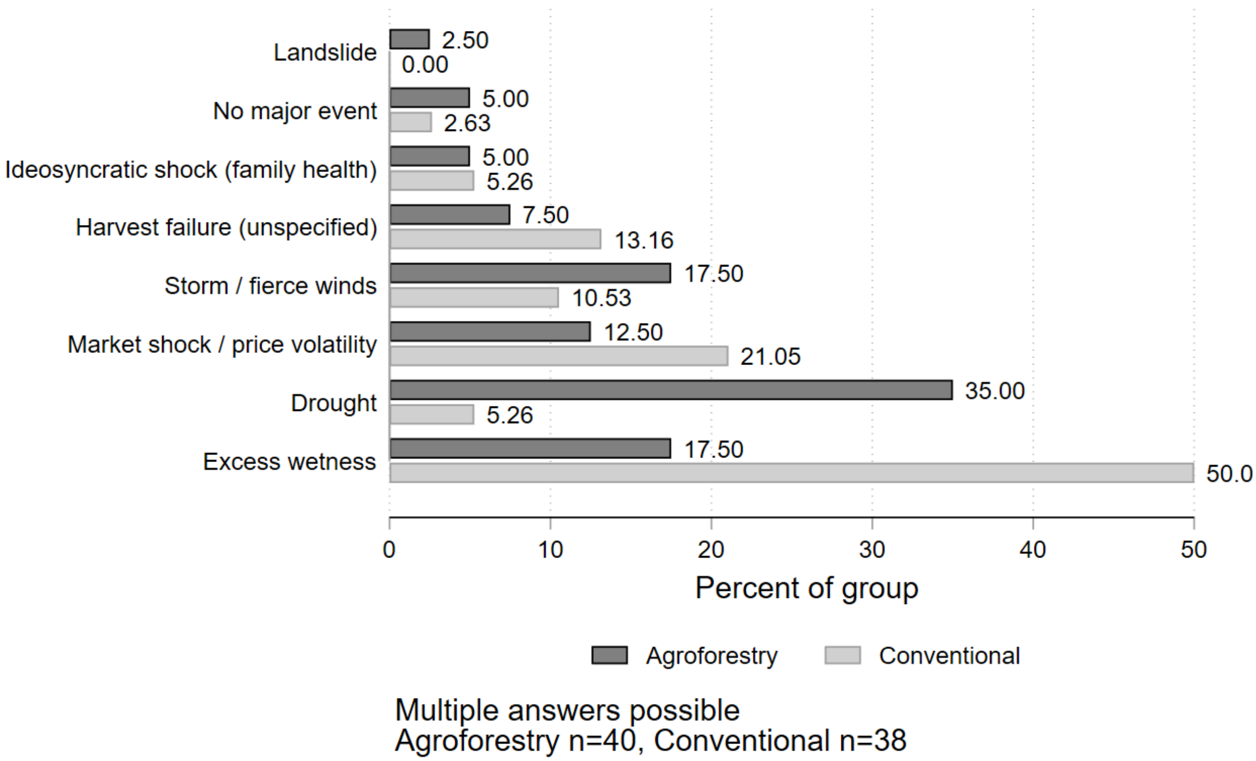

Figure 27: Major shocks experienced

While for *Agroforestry* about 35% of household reported that drought is the major problem affecting their livelihoods the opposite was true for the *Conventional* group where 50% of respondents reported excess wetness as most impactful shock in the past 5 years.

The study participants were asked how they responded to a shock (open listing) with possible options. A total of 13 coping strategies were mentioned, of which 8 were coded as positive and 5 as negative (Figure 28). In the *Agroforestry* group, the major positive coping strategies of households were to increase input (25%), to resolve it within the household (22.5%, without further specification) change the main crop (7.5%) and selling of assets, such as trees and livestock (7.5%). Major negative coping strategies were to endure it (12.5%, sitting it out – without further specification) and to reduce investment in seasonal and perennial cropping (2.5%).

In the *Conventional* group, the major positive coping strategies of households were to change the main crop (18.42%), to increase input (13.16%) and to resolve it within the household (13.16%, no further specification). Major negative coping strategies were to access informal credit (34.21%), to sit it out (7.89%, without further specification), and to access formal credit (7.89%).

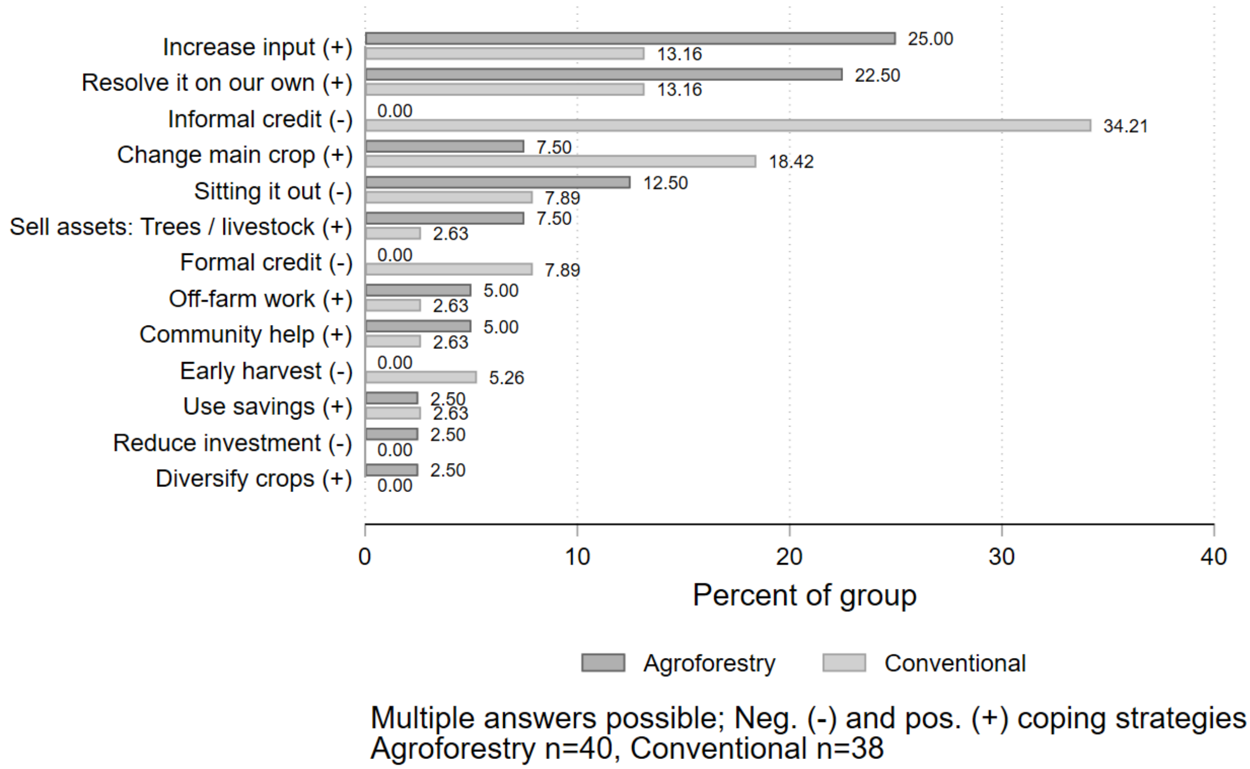

Figure 28: Coping strategies

The households were dichotomized into groups according to them using positive or negative coping strategies with the assumption of negative outweighing a positive coping behaviour. Therefore, in case a household used both, they were categorized as using negative coping strategies. A total of 71 (91.03%) of households that answered the question were considered for analysis. Four households, equally applying strategies and distributed in both groups, were not considered. Similarly, three households (2 in *Agroforestry*) reported no events and no coping strategies. In the *Agroforestry* group, 83.33 % of households applied positive coping strategies, whereas in the *Conventional* group 60% of households applied negative coping strategies. A χ^2-test of independence revealed that the groups of *Agroforestry* and positive coping strategy were moderately related (Pearson's $\chi^2(1) = 14.140$, Cramér's V=0.446, p<0.01). However, the correlation between the categorization into coping strategies and the original hamlets was lower in magnitude by 10pp (Pearson's $\chi^2(1) = 8.420$, Cramér's V=-0.344, p<0.01), suggesting that differentiating households into strategies is more meaningful in explaining coping behaviour.

In terms of households categorized into positive and negative coping strategies, differences between resilience measures were investigated with Student's t-test and ordered logistic regression. On average, the positive coping category had higher mean differences in calculated resilience scores (T-test, mean-diff.=0.088, p<0.01), buffer capacity (T-test, mean-diff.=0.041, p<0.01), capacity to learn and adapt (T-test, mean-diff.=0.151, p<0.01) and capacity for self-organisation (T-test, mean-diff.=0.12, p<0.01) suggesting a consistent relationship between calculated resilience and coping behaviour.

Finally, the odds-ratios of binary logistic regression were considered as suitable measure to understand how the resilience dimensions influence the likelihood of a positive coping strategy with clustered standard errors at livelihood strategy group level. For a dichotomous dependent variable, the parallel line assumption of ordinal logistic regression does not need to be fulfilled. The dependent variable of positive/negative coping strategy was explained with the subdimensions and strategy category. Thus, it is reasoned that the choice of coping strategy depends on resilience capacities and dominant livelihood strategy. Table 20 shows regression outputs. Values in text below are reported including standard errors in brackets.

Table 20: Odds of choosing a positive coping strategy (logistic regression, Wald's)

Dependent variable:	Positive Coping Strategy	
Obs. (n=71)	Odds ratio	Std. Err.
Buffer capacity	1.726**	0.461
Capacity of learning and adaptation	1.136***	0.015
Capacity of self-organisation	1.454***	0.105
Conventional strategy	0.348***	0.006
Constant	0.013***	0.013
Pseudo R^2 (McFadden's)	0.219	
Log pseudolikelihood	-36.856	

Note: Significance threshold α at 0.1, 0.5** and 0.01** for a 10 pp (0.1 index-score) increase in capacities*

For a 10pp (realistic magnitude of 0.1 at indicator range [0-1]) increase (cet. par.) in the respective capacities the odds for employing a positive coping strategy were largest for buffer capacity with 1.726 [0.461] (p<.01), second for capacity for self-organisation with 1.454 [0.105] (p<0.01) and smallest for capacity for learning and adaptation with 1.136 [0.015] (p<0.01). Following the *Conventional* strategy lowers the odds of employing a positive strategy to 0.347 [0.006] (p<0.01). These test results add to the construct validity of the resilience indicator and the results of *Agroforestry* being the more resilient group that has a higher likelihood of choosing positive coping strategies.

6. Discussion

Diversification of income and farms helps smallholders in SEA and Indonesia to sustain their livelihoods on relatively small parcels of land (Rigg & Salamanca, 2017). On the other hand, intensification and specialization into highly productive cropping systems allow farmers to better their livelihoods, while increasing dependency on a specific production system, degrading the natural resource base, and increasing livelihood vulnerability (Griffin, 2020). Diversified systems enable households to smooth consumption over lean periods and respond to climatic and market shocks to foster their food and income security and overall livelihood wellbeing (Ellis, 1998). While the impacts of climate change are increasingly impacting smallholder livelihoods in SEA and Indonesia (Djalante et al., 2017; Keil et al., 2007; Marfai et al., 2008), diversified agroecological systems are a viable alternative for sustaining households while increasing output and income, preserving the natural resource base and fostering livelihood resilience (Altieri et al., 2015; Ota, Herbohn, et al., 2020).

Livelihoods in Central Java are increasingly threatened by effects of climate variability and extreme weather events, such as droughts, extreme precipitation, and fierce winds (Djalante et al., 2017; Keil et al., 2007; Utami et al., 2018). Additionally, several watersheds are impacted by soil erosion from intense farming in the uplands which also increases landslide risk. The Merawu Watershed and the upstream villages of Leksana and Penanggungan offer a window into this complex nexus of livelihoods and farming, natural resource degradation and the impact of climate and market shocks (Hobo et al., 2020; Sari et al., 2020; UGM, 2017). Explicating the two suspected prevalent livelihood strategies of intensified cropping and diversified crop-livestock systems with agroforestry were the focus of this thesis. The present study set out to untie this interconnected research problem by addressing three key research questions on livelihood strategies, resilience and coping mechanisms as outlined in the consecutive chapters. An agroecological livelihood resilience indicator system was used for assessment (Ifejika Speranza et al., 2014; Jacobi et al., 2018; Quandt, 2018).

Overall, this research was able to ascertain conclusive results. The three working hypotheses of this study postulated that livelihood strategies associated with agroecology i) have higher resilience (H1), ii) higher income (H2), and iii) apply more positive coping strategies (H3). First, hypothesis ***H1: Livelihood strategies associated with agroecology have higher income*** could not be confirmed as capita income did not differ significantly. However, hypothesis ***H2: Livelihood strategies associated with agroecology have higher levels of resilience*** could not be rejected as the identified *Agroforestry* type had on average 12.2. pp higher levels of resilience. Third, hypothesis ***H3: Livelihood strategies associated with agroecology are more likely to employ positive coping strategies*** could not be rejected as a 10 pp increase in each dimension of resilience were associated with increased odds, while the *Conventional* strategy was associated with reduced odds to implement positive coping strategies. The consecutive sections offer a detailed discussion on the results.

6.1. Income and livelihood diversification

The first set of research questions dealt with differences between villages and respective livelihood strategies.

6.1.1. Poverty trends, policy, and structural considerations

First, the socio-economic status of households in terms of income was ascertained to present a holistic view and approximate Córdoba Vargas (2020) suggestion for an in-depth inclusion of power structures, hierarchies, and inequality analysis in resilience assessment. Generally, poverty has been in decline in rural Indonesia from about 20% of the population in 2007 to 14% (national rural poverty line) in 2016 (OECD, 2019).

In Java, poverty is generally determined by educational attainment, the number of household members, physical assets, employment status, health shocks, the microcredit program, access to electricity, and changes in employment sector (Dartanto & Nurkholis, 2013; Sriyana, 2018). The present study first compared household income to both regional average wages and average minimum wages, and then analysed the prevalence of poverty.

The finding that the intensively farmed Penanggungan village area has a slightly lower poverty rate corresponds to the findings of Wardhana et al. (2017). They describe the effect of regional agro-clusters in Central Java which increase employment opportunities, and lead to a specialization on a single crop. Further they reduce poverty locally but also exert regional spill-over effects on neighbouring villages. Similar to the rest of SEA, this makes the agricultural sector the engine of economic growth in rural Indonesia as its development induces growth in linked sectors (de Janvry & Sadoulet, 2010; Kadir & Amalia, 2016; Suryahadi et al., 2012). Rural welfare levels are thus influenced by increased incomes in agriculture and the development of the off-farm economy and growth of productivity in both sectors has potential to reduce rural poverty (Kadir & Amalia, 2016). However, it seems that targeted programmes that stimulate the rural non-farm economy are more effective than general economic growth or infrastructure investment (Prasetiya & Pangestuty, 2012). Peer pressure in adoption of highly-profitable crops that cause vulnerability and natural resource base degradation in the long term is suspected to play a key role in agro-clusters (D. Wardhana et al., 2020). Overall, market focused development may have negative implications for household resilience (Rigg & Oven, 2015).

Market access and rural infrastructure is argued to be a major determinant of livelihood strategies (Ellis, 1998). According to the review of Ota et al., (2020), choice for intensification strategy (which has welfare implications) is determined by how close the farmer is to the market. Penanggungan had better continuous access to a road network in good conditions, but both villages profited from the recent Village Fund Transfer used for infrastructure development. In other studies of rural Indonesian livelihoods, the establishment of accessible quality roads and energy supply has been shown to stimulate the rural non-farm economy with associated employment and income effects as elaborated above (Gibson & Olivia, 2010). However, despite efforts to decrease income inequality and poverty with the establishment of the Village Fund Transfer, evidence suggests that agricultural development and fostering human and social capital has a larger effect on the wellbeing of rural livelihoods than direct infrastructure investment (Arham & Hatu, 2020; Prasetiya & Pangestuty, 2012).

Social capital has been argued to be the catalyst in rural transformation and poverty reduction in Indonesia (Nasution et al., 2015; Rustiadi & Nasution, 2017). Rustiadi and Nasution (2017) define social capital as having five components which are roughly equivalent to the combination of social capital, political and cooperation, and networks in the present study: groups and networks, trust and solidarity, collective action and cooperation, information and communication, social cohesion and inclusion, and empowerment and political action. Corroborating and complementing their results, the present study found significant yet weak positive associations of household income with human capital (Kendall's $\tau_b = 0.160$, p<0.05) and with social capital (Kendall's $\tau_b = 0.369$, p<0.1). In terms of social capital and in the context of the present study this means that higher earning households are members of more community groups, show higher attendance and participation, and can rely on community group support during crises. However, no association of higher levels of household income with the sub-dimension of cooperation and networks (trust, reciprocity, savings group activity) could be found. This highlights the importance of community groups and their contribution to livelihood outcomes similar to (Utami et al., 2018).

Apart from macro-economic developments and micro-social community interactions that build on households' social capital, choice of farming strategy and composition of income are major determinants of livelihood outcomes, wellbeing, poverty, and resilience.

6.1.2. The adoption of agricultural strategies and consequences for livelihoods and the environment

Households in the villages differed significantly in farm diversity, input intensity, and access to infrastructure. Given that the villages are geographically situated relatively close to each other but were associated with such distinct livelihood and farming strategies, it is likely that district policies and workshops provided by the agricultural extension service and PT. Indonesia Power influenced whether agroforestry elements are adopted (compare Hobo et al., 2020; Sari et al., 2020).

Generally, diversification of farming in Central Java is determined by market demand, but also by the availability of labour force in the family, dependency ratio, means of transportation, land holding size, access to irrigation, and training and extension service access (Glover et al., 2013; Qanti et al., 2017; A. Wardhana et al., 2017). These findings are only partially supported by the present results, extension service access was better in the *Agroforestry* group, while labour availability, labour force in the family, and access to irrigation was larger in the *Conventional* strategy. Moreover, operated land area was with 0.8 ha of land close to the regional average which roughly qualifies farms as sub-livelihood size (Rigg and Salamanca 2017).

The majority of smallholders in Leksana followed a more diversified approach that included crop-livestock systems with high share of agroforestry, similar to other systems in the region (Lastiantoro, 2015; Rahman, Sunderland, Roshetko, et al., 2016; Sembada et al., 2019; Seruni et al., 2021). Incomes were generally comparable to other more diversified systems; however specialized livestock systems that focused on cattle (beef and dairy) or chicken (broilers and laying hens) outperformed integrated crop-livestock system by far (Hariyanto et al., 2021; Soesilowati et al., 2018). In the integrated crop-livestock-agroforestry system, the cropping of high-input-high-profit crops such as cabbage and chili can be regarded as high-risk strategy with considerable impact on the environment (Bhattarai & Mariyono, 2016). However, low levels of livestock keeping was common in this group and balances the impact on the environment and the risk to unstable household income. Diversified farming systems that integrate crop-livestock based synergistic nutrient cycles have been proven to be more sustainable in West Java (Sembada et al., 2019). Further, the planting of protein rich trees for feed complements the on-farm nutrient cycle and further decreases soil erosion. Integrated livestock-crop systems as practiced in the *Agroforestry* group are thus generally more sustainable (Rosmiati et al., 2020).

Agroforestry and diversified crop-livestock systems usually based on local culture and knowledge systems (Hernawan et al., 2020). This notion is supported by the diversity and amount of SWC strategies applied in the *Agroforestry* strategy; a finding that is corroborated by Hobo et al.'s (2020) result that villagers in Leksana rely on local and traditional wisdom in their choice of farming strategy. The finding that diversification of cropping patterns was related to high-risk perception (impact and probability), being risk averse, and economic motivation in a West Java study (Mutaqin & Usami, 2020), can be related to the higher levels of environmental awareness exhibited in Leksana (Sari et al., 2020). The present results suggest that farmers following the *Agroforestry* strategy are aware of the environmental consequences of their land use and adjust their agricultural strategy accordingly with more SWC strategies, while using trees and livestock as economic safety nets.

Overall, agroforestry farm systems have high ecological stability (Hernawan et al., 2020), which is corroborated by the geospatial analysis that shows that land improvement outweighs land degradation. Generally, implementation of agroforestry is an effective strategy to decrease soil erosion in watersheds and is especially suited for dryland agriculture as common in the uplands of Central Javanese watersheds (vs. rice paddies) (Andriyani et al., 2017; Inoue et al., 2003; Kosuke et al., 2013). Typically, agroforestry systems have high above ground carbon stock and higher levels of species diversity (Wiryono et al., 2016).

Generally, policy and agroeconomic modelling for agroforestry implementation in Central Java suggests benefits for farm income, livelihood resilience, biodiversity, and carbon sequestration (Nöldeke et al., 2021). Maximum plant diversity and intermediate levels of income have been shown to go hand in hand (Okubo et al., 2010), and agroforestry can contribute significantly to farmers income in the humid tropics and Indonesia (Hernawan et al., 2020). Simulations show that integrated agroforestry systems (e.g., multi-storey home-gardens, alley cropping, border planting, etc.) outperform a farm mosaic approach in terms of cumulative production and return (Paul et al., 2017). Further, projections suggest that agroforestry can achieve up to 21% higher economic returns as compared to monocropping under climate change impacts (ibid.).

Further, multicropping patterns proved to be more sustainable and competitive in West Java (Arsanti & Böhme, 2015). While none of the present results suggest higher household or per capita incomes for the *Agroforestry* strategy, the combination of seasonal and perennial crops enables farmers of this group to achieve a higher benefit-cost ratio. Thus, their farming style is more efficient as compared to the *Conventional* strategy. Economies of scope and beneficial tree-crop interactions make agroforestry an economically efficient diversification strategy (Paul et al, 2017). Moreover, maximizing tree element density with stratified and multi-layered canopies consisting of high value timbers and multi-purpose trees are suggested to increase farm profitability within perennial crop-based agroforestry systems in West Java (Okubo et al., 2010).

A major determent of adoption of agroforestry, as well as increased production and productivity are trainings and guidance by governmental extension service officers or similar (Nuryati et al., 2019). Further, income in diversified vegetable farming is generally improved by participation in farmers organisations (Jahroh, 2010). Studies in other areas on rice farming show that government training and extension service assistance increases technical efficiencies of cropping, whereas farmer groups alone do not increase technical efficiency of cropping (Hakim et al., 2021). The present results corroborate the findings of Rahman et al. (2016), that government training and farmers groups are crucial in the adoption of agroforestry. A more detailed review on the influence of social capital on the adoption of agroforestry is given in the resilience discussion section below.

Low participation in farmer groups is a key reason why smallholders in rural Indonesia are not open willing to switch crops to more productive and more sustainable crops (Suprehatin, 2019). Monocropping patterns are determined by input cost, profitability, labour supply, capital and credit, and input supply (Arsanti & Böhme, 2015). The present results confirm this as Penanggungan was associated with the *Conventional* strategy, a high input system focused on cropping of the highly profitable potato crop similar to the potato boom in the adjacent Dieng Plateau (Griffin, 2020). Farm inputs were estimated to be almost ten times higher than in Agroforestry. While the input intensity improves profitability and revenue-cost ratio of the potato system (Arifin et al., 2021), it has considerable detrimental effects on long term livelihood stability and the natural resource base (Griffin, 2020). Crop booms such as the potato boom allow farmers for a while to accrue considerable profits on sub-livelihood sized lands (Rigg & Salamanca, 2017). However, while results evidently suggest that household incomes were significantly higher for the *Conventional* strategy, no difference in per capita incomes existed, but a decrease in potato cropping output over the last decades was noticeable (Sari et al., 2020). Further, geospatial analysis results revealed high levels of land degradation over the last two decades.

The choice for a monocropping strategy is usually related to a low risk perception or risk neutrality, as was the case in West Java (Mutaqin & Usami, 2020). Improving awareness about the negative impact of risks from monocropping and increased sensitivity towards climate impacts is suggested to increase farm diversification (ibid.). While the main motivations of farmers taking up Agroforestry was its use as economic safety net, followed by using it for soil and water conservation purposes (78.43% of responses), major reasons against implementation where the perceived negative impact on crops through shading and water retention as well as profitability considerations (83.87 % of responses). Principally, in the humid tropics shade from agroforestry elements is not detrimental for seasonal crops but rather species-species interactions need to be paid attention to and proper management systems need to be integrated (Manurung et al., 2008; Ota, Herbohn, et al., 2020).

These results and the findings about low levels of farmer group participation the lack of access to governmental extension service suggest the need for technical knowledge transfer and material support for the adoption of agroforestry (compare Rahman et al., 2016). The successful case-study in the Sewu Hills of Central Java shows the importance of technical and managerial knowledge transfer in the establishment of agroforestry for protecting the natural resource base (Nibbering, 1999). Furthermore, across SEA evidence suggests that social capital building interventions which include farmer field schools that transfer of technical and managerial knowledge on agroforestry as well as seedlings and ownership of decision-making causes changes in farming strategies (Dendi & Shivakoti, 2003; Landicho et al., 2019; G. E. Sabastian et al., 2019; Uy et al., 2011).

In the *Conventional* strategy, the reasons to not adopt agroforestry suggests that mental models, beliefs, and identity shape the perception of the benefits from agroforestry, possibly originating from earlier unsuccessful implementations (compare Klein, 2017; and World Bank, 2014). This stresses the need to integrate behavioural components in development interventions and highlights the use of the SLF as analytical concept that produces actionable results (De Haan, 2012b; DFID, 1999; Scoones, 2015).

Apart from behavioural interventions, strong land tenure rights, and institutional and financial support for resource-poor smallholders is needed in addressing the trade-off between short term crop income loss and long-term and mid-to-long-term economic gain from the implementation of agroforestry in the transition period (Rahman, Sunderland, Kshatriya, et al., 2016; Tittonell, 2020). Financial liquidity is indeed a major constraint that hinders horticultural farmers in the Javanese uplands to switch to agroforestry Kawashima et al 2011). Returns on investment that are needed for consecutive input and short cycles of production do not allow Conventional farmers to switch to agroforestry which has longer production cycles and delayed returns (compare Sabastian 2019). However, agroforestry systems in Central Java have been found to have higher net present value than conventional cropping systems (Rahman, Jacobsen, et al., 2017). Furthermore, they have been found to be more resilient. Payment for Ecosystem Service schemes could provide a viable option of accruing international funds to subsidise the preservation of commons by upland smallholders (Idol et al., 2011; Neef & Thomas, 2009).

Overall, a variety of major differences between the two identified livelihood strategies exist. Findings about *Agroforestry* are in line with Ota et al.'s (2020) review on the effect of reforestation of livelihoods. While the *Conventional* system is considerably more profitable, it has no clear advantages to the more efficient *Agroforestry* system while having detrimental consequences on livelihood stability and the natural resource base. In fact, the present study found a moderately positive correlation between farm efficiency (benefit cost-ratio) and livelihood resilience.

6.2. Agroecological livelihood resilience

The second set of research questions inquired into livelihood resilience of the respective livelihood strategies. This agroecological resilience assessment found conclusive results, as *Agroforestry* consistently exceeded *Conventional* by on average 15.8 pp across all dimensions and by 12.2 pp in overall livelihood resilience. In subdimensions, 12 of the 16 sub-dimensions (75%) scored significantly higher in *Agroforestry*, suggesting low compensability and high internal validity of the indicator construct. The findings are in line with several theoretical, conceptual, and empirical studies that suggest that agroecology and agroforestry increase livelihood resilience of smallholders and food systems (Altieri, 2009; Altieri et al., 2015; Ifejika Speranza et al., 2014; Jacobi et al., 2018; Lasco et al., 2014; Ota, Herbohn, et al., 2020; Prabhu et al., 2015; Quandt, 2018; Saikia et al., 2017; Waldron et al., 2017).

The findings also suggest that stated wellbeing can be considered a relevant direct measure of resilience, as a weak positive and significant association with buffer capacity was found (Quandt, 2018). However, of overall household resilience and amongst the three dimensions only buffer capacity was clearly associated with stated wellbeing, which corroborates Quandt's (2018, p. 18) validation approach and finding that *"using the sustainable livelihoods approach to measuring livelihood resilience is an effective methodological approach".*

6.2.1. Buffer capacity

The buffer capacity dimension of resilience signifies the ability of a household to immediately respond to shocks as well as the ability to design systems that are responsive to shocks or absorb system perturbations them without changing their identity. It thus bridges anticipatory and adaptive capacity (Ifejika Speranza et al., 2014; Jacobi et al., 2018; Quandt, 2018). *Agroforestry* scored significantly higher in 3 out of 6 sub-dimensions and overall buffer capacity. This result corroborates Quandt's (2018) finding in rural Kenya where agroforestry raised all livelihood capital scores by on average 10% as compared to other systems.

Natural capital was significantly but only marginally higher by 6.4 pp in the *Agroforestry* group. In the respective variables, *Agroforestry* significantly outperformed *Conventional* in soil condition specific indicator variables (e.g., easiness to work the soil). However, *Agroforestry* group reported more twice as many problems with soil erosion and soil conditions during the dry season, as well as problems with droughts in general. In the *Conventional* group, smallholders mainly reported a decrease in soil fertility but also had significantly more advanced irrigation technology to prevent droughts. In Central Java irrigation technology has been key in fostering livelihood stability during drought events and consecutively lift households out of poverty, which contributes to the understanding of higher incomes and lower poverty rates in *Conventional* (Hussain et al., 2006). The perceptions of soil related problems do not contradict the initial geospatial analysis and findings regarding the higher levels of land degradation in Penanggungan as Sari et al. (2020) comment that farmers in the associated village of Leksana are more aware of environmental problems. Generally, soil erosion has been a long-standing problem in the uplands of Central Java (Kusumandari & Mitchell, 1997; Labrière et al., 2015; Marfai et al., 2008). Local policy has encouraged the implementation of agroforestry through the green economic policy framework approach, workshops by extension service and PT Indonesia Power, all of which are suspected to significantly reduce erosion load in the Merawu watershed while significantly raising incomes and fostering farming sustainability in the uplands of Central Java (Hobo et al., 2020; Sari et al., 2020).

While the geospatial analysis in Section 1.4 visualises the amount of deforestation and land degradation of the *Conventional* strategy, the household-economic analysis could not find a significant difference between per capita incomes. Thus, while *Conventional* has a higher revenue and turnover, no clear financial incentive exists for the implementation of the intensification strategy. However, the intensification strategy has serious environmental and agro-ecological drawbacks that increase livelihood and farming vulnerability (Chandler & Reid, 2016; Ribot, 2013). The geospatial and survey-based findings therefore coincide with Griffin's (2020) results in the adjacent Dieng Plateau where intense potato farming causes increased livelihood vulnerability from high input dependency and degradation of natural resources. Given that potato farming contributes to, on average, 60-70% of household incomes in the *Conventional* strategy, this high dependency increases vulnerability and is slightly reminiscent of other crop booms that severely impacted the natural resource base (Li, 2014; Mahanty & Milne, 2016; Münster, 2015; Rigg et al., 2016).

Generally, in comparison to land-sparing natural protected sites, agroecology and especially agroforestry can be seen as a land-sharing strategy in conservation, with the dual aim to generate high output and income and preserve ecosystem goods and services as well as biodiversity (Alteri, 2009; Franzluebbers et al., 2020; Ota, 2020). While evidence suggests that cash crop production increases by the ecosystem services secured by agroforestry, the present study finds no evidence for higher profitability in *Agroforestry* (Altieri, 2009; Jat et al., 2020; Nissen et al., 2001; Ota, Chazdon, et al., 2020; Sinclair et al., 2019).

However, general *financial capital* was marginally lower in the *Conventional* group than the *Agroforestry* group, which is dependent on selected indicators. While both groups operated on comparable farm sizes, the *Conventional* group owned, on average, significantly less livestock than the *Agroforestry* group. Livestock ownership positively contributes to adaptation strategy decisions and capacity building, and increasing ownership is a key policy recommendation to increase livelihood resilience of smallholders in Central Java (Irham et al., 2018).

In terms of farming equipment, no overall difference was ascertainable, however *Conventional* smallholders owned more sophisticated irrigation and pesticide equipment, while *Agroforestry* households owned more manual appliances. Selling of these liquid assets can be a key (negative) coping strategy that helps households smooth consumption during shocks (Keil et al., 2007). The higher levels of access to formal and informal credits may explain the high level of investment and the ongoing *'constructed precarity'* or high livelihood vulnerability in conventional (Rigg et al., 2016). Access to credit allows to establish higher levels of income by using high levels of input for more profitable farming systems (Keil et al., 2007; Lee & Widyaningrum, 2019; Mariyono, 2019b; Mutaqin, 2019), i.e., it helps smallholders to *'step up'* (Dorward et al., 2009). However, in times of crises credits may serve to smooth consumption in case of crop failure, which is considered a negative coping strategy due to long term consequences on missing capital for agricultural investment (Pandey & Bhandari, 2009).

Income diversification was significantly more pronounced in *Agroforestry* as *Conventional* focused on seasonal cropping. Generally, income diversification is seen as a key measure to increase livelihood resilience as households reduce their dependency on a single source (Ellis, 1998; Schwarze & Zeller, 2005). The results from the present study are in line with the findings of Ota et al.'s (2020) review on the effects of agroforestry on livelihoods, where agroforestry is expected to increase the financial capital of a household (compare Altieri, 2009; D'Annolfo et al., 2017; Jat et al., 2020). In the humid tropics, planting trees as savings and economic safety net form a major incentive for implementing agroforestry (Keil et al., 2007; Niehof, 2004; Ota, Chazdon, et al., 2020). The long maturity period can be shortened by planting fast growing value timber species such as the fast growing *Paraserianthes* *falcataria* tree or planting multi-purpose tree species, such as fruit or feed trees (G. Sabastian et al., 2014; G. E. Sabastian et al., 2019). Trees can be used as security for loans and are windfall profits that can be used to increase investment, change farming strategies or pay for important family events which can often have impoverishing effects on households (Banerjee & Duflo, 2007; Ota, Herbohn, et al., 2020). However, the full financial benefits from reforestation are often not realized as smallholders need managerial and technological knowledge which is sometimes difficult to impart depending on rurality and geographical characteristics (Arvola et al., 2020; Glover et al., 2013; Grass et al., 2020).

While the literature suggests that increased *human capital* (education and experience, larger households) contributes to implementation of agroforestry, the present study cannot confirm this suggestion (Arvola et al., 2020; Glover et al., 2013; Grass et al., 2020; Ota, Herbohn, et al., 2020). However, higher levels of household member education have a significant and positive association with the choice for Agroforestry strategy and thereby resilience (Kendall's $\tau_b = 0.193$, p<0.1). Nonetheless, given that households, labour availability and labour amount in the Agroforestry group are smaller the results coincide with the findings of Ota et al.'s (2020) review that Agroforestry can be favoured over other farming strategies if the alternative livelihood strategy is more labour demanding.

Physical capital was found to be significantly more developed in the *Conventional* group. While general market access was similar between the two groups, road conditions during the wet season were worse in the *Agroforestry* group. This corresponds to the choice for intensification process being influenced by market access (Otsuka et al., 2016). Similarly, access to household and irrigation water and technology was significantly worse in the *Agroforestry* group, which may partially explain their lower farm profitability (Hussain et al., 2006). However, agroforestry protects the homestead by slowing wind speed, decreasing runoff erosion and landslide risk and increasing the soil water retention capacity, all of which is difficult to measure in an indicator (Altieri, 2009; Altieri & Nicholls, 2017; Ota, Herbohn, et al., 2020; Smith et al., 2017).

Social capital was overall higher in the *Conventional* group. Generally, *social capital*, such as community group membership and support in preparation for, during and in recovery from shocks is invaluable. This "informational capital" helps rural households to anticipate, prepare for or adapt to shocks, or better their coping options (Aldrich, 2015; Guarnacci, 2016; Partelow, 2021; Tasic & Amir, 2016). Theoretically social capital is closely related to general resilience in social ecological systems (Adger, 2000), which can be confirmed with a correlation of social capital to buffer capacity (Spearman's $\rho = 0.2486$, p<0.05), but not the other dimensions or overall resilience. Evidently social capital is highly related to livelihood vulnerability and resilience in rural Indonesia (Tjoe, 2016; Utami et al., 2018). During crises *Conventional* households expected to receive more support in terms of labour and cash donations. However, *Agroforestry* households expected to receive more support in terms of moral support and in-kind donations. Stronger formal institutionalism prevails in the *Conventional* group where community group membership was twice as high and group participation was almost 30% higher as in *Agroforestry*. These findings do not coincide with Ota et al.'s (2020) conclusion that the effect of reforestation on social capital is mostly positive as community engagement, collective action, and exchange of knowledge and skills are often enhanced. The effect of *social capital* is suspected to occur mainly in terms of dedicated community groups (e.g. farmer's group), which introduce a mutually reinforcing positive cycle of participation and implementation of agroforestry in the community (Holt-Giménez et al., 2021). The results differ mainly because farmers groups were not considered in social capital of the buffer capacity dimension but rather included in other relevant sub-dimensions of complementary resilience dimensions. The *Agroforestry* group had, overall, a significantly higher farmer group membership and participation. In the associated village higher awareness of environmental consequences of farming were present which suggests and increase in farmers capabilities and knowledge (Hobo et al., 2020; Sari et al., 2020).

Finally, *farming diversity* measures diversification of income, crops and livestock, as well as the implementation of agroforestry, all of which indicate livelihood diversification and a more resilient livelihood overall (Altieri et al., 2015; Jacobi et al., 2018). Farm diversification was generally higher in the *Agroforestry* group, with higher diversity of crops and animal breeds. Most importantly the share of land under agroforestry was the deciding element in differentiation between the two livelihood strategies. The results are relevant for agroecological resilience assessment. For example, evidence from South-East Asian uplands suggests that agroforestry systems had shorter recovery time after natural disasters due to their increased environmental and economic buffers as well as fruit trees that support household food security during lean periods (Magcale-Macandog et al., 2010; Simelton et al., 2015; van Noordwijk et al., 2014). Thus, agroforestry can support households before, during and after a crises – depending on implementation style and species selection (Fedele et al., 2016).

6.2.2. Capacity for learning and adaptation

Capacity for learning and adaptation indicates a household's ability to profit from training and best practices shared by neighbours regarding livelihood strategies and resilience (Ifejika Speranza et al., 2014). It was twice as high in *Agroforestry* compared to *Conventional*. The effect is specifically caused by large differences in knowledge of threats and opportunities, reflective and shared learning, traditional ecological knowledge, and shared visions in the community.

Knowledge of threats and opportunities indicates the anticipatory capacity of household towards hazards and shocks and was twice as high in *Agroforestry* than in Penanggungan. In this sub-dimension the major difference between the groups may be explained by the presence of agricultural extension services in the hamlets of Wanasari/Tamansari and its absence in Penanggungan II. The absence of services limits farmers understanding of climate variability, market shocks and opportunities. Further it limits their anticipatory and adaptive capacities and has negative implications for overall farm performance (Luther et al., 2018; A. Pratiwi & Suzuki, 2017). Knowledge about threats and adaptation options have been shown to significantly influence livelihood strategies that are associated with higher adaptive capacity in Central Java (Irham et al., 2018). In the present study, Agroforestry showed on average more than 12 pp higher resilience, and participation in government owned farmers training was twice as high than in *Conventional*. High participation in farmer field schools is desirable as it has been effective in introducing new skills, technology and knowledge into smallholder's lives and benefited on all five livelihood capitals (Mariyono et al., 2021). However, no significant differences in awareness of potential hazards or shocks existed between the groups, nor in respective coping mechanisms; leading to the conclusion that awareness of hazards is generally well established.

The *reflective and shared learning* sub-dimension indicates the household's ability to reflect on livelihood strategies and share learnings with neighbours or between communities (Ifejika Speranza et al, 2014). Smallholders in *Agroforestry* scored on average almost twice as high than their counterparts in *Conventional*. First and favourable, community-based trainings for members of the same or other communities, and second and more problematic (pesticide-) company owned workshops, were more frequent for *Agroforestry* group members. The practice of sharing best practice farming strategies and participation in agricultural trainings and farmers group generally increases farm output, sustainability of agricultural practices and resilience (Gultom & Joyce, 2014; Kerr et al., 2016; Luther et al., 2018; A. Pratiwi & Suzuki, 2017; Rustinsyah, 2019). About 22.5% of farmers in the *Agroforestry* group indicated learning from neighbours, whereas in *Conventional* the effect was rather low with only 7.9%. Farmers groups help overcome barriers to farm strategy change by exchanging best practices in a group setting. Especially economically disadvantaged community members profit from farmers group participation as they often lack access to information crucially relevant to their livelihood (Yusup et al., 2016). However, the rate of participation of 94.6% in *Agroforestry* was three times as high as in *Conventional* suggesting that a rather low rate of knowledge exchange happens in a more competitive intense farming environment. While conceptually this dimension is strongly associated with social capital, empirically no association was ascertained, suggesting that two separate aspects of community interactions were found (Ifejika Speranza, 2013; Ifejika Speranza et al., 2014).

Functioning Feedback mechanisms contrasts the inter-household exchange perspective and focuses on systemic feedback mechanisms that influence farming style and adaptation to - but also recovery from - hazards and shocks, i.e., it explicates support systems for smallholders (Ifejika Speranza et al., 2014). Generally, the sub-dimension was more pronounced in *Agroforestry* suggesting that the attention of extension service does make a difference (Ashkenazy et al., 2018). Both, governmental subsidies (seeds, seedlings, fertilizer, pesticides) and participation in integrated pest management schools was higher in *Agroforestry*. Thus, the significant differences in pesticide input between the communities is possibly related to a knowledge gap, as only 10% only in *Conventional* but nearly half of *Agroforestry* participated in an IPM. This possibly has significant implications for human and environmental health due to the high pesticide use in the intensely horticulturally used area (Mariyono, 2018; Nurbudiati & Wulandari, 2020; Setiawan & Inayati, 2020; Widayati et al., 2017; Yuantari et al., 2015).

Existence and use of local and traditional knowledge are important factors to increase resilience as farming style and livelihoods are adapted to the local bio-climatic conditions (Berkes et al., 2000; Berkes & Folke, 1994; Hosen et al., 2020). It was significantly higher in *Agroforestry* by 43.6% due to the extensive use of SWC techniques such as terracing, inter- and multi-cropping, manuring, establishing soil bounds and using contour farming. However, *Conventional* used more crop rotation and plastic covering techniques. Given how prone the area is to erosion, soil management strategies help to preserve fertile topsoil layers (Hobo et al., 2020; Sari et al., 2020). Especially the village of Leksana which is associated with agroforestry relies more on local wisdom as compared to Penanggungan (Hobo et al., 2020). All of these strategies have been shown to significantly contribute to farmers adaptive capacity in central Java (Irham et al., 2018). Next, the consumption of local staple foods (e.g., cassava and Indonesian corn rice *Nasi Jagung*; Utami 2017, Ch. 2, Utami et al., 2018) was significantly higher in *Agroforestry*, where on average 6.7/21 weekly meals were consumed without rice as compared to *Conventional* (3.26). Given that poverty rates are comparable this suggests an intentional reliance on locally sourced produce. *Agroforestry* farming technique was included in the sub-dimension since it has been established for 30-50 years in the area and is a preferrable successor to shifting cultivation. Interestingly 23.68% of farmers in *Conventional* indicated that they implemented agroforestry which indicated at most a few trees along terraces and soil bounds to prevent erosion (Suryanto et al., 2012). This finding is congruent with the observations of Sabastian et al. (2014, 2019), Rahman (2017), and Tunguay et al. (2020), that agroforestry is implemented in a wide variety of forms in Central Java, amongst the which the planting of trees to fortify soil bounds with fruit or feed trees is the most common implementation in smallholders that follow more intensified cropping strategies. The village of Leksana, where the majority of farmers follow the *Agroforestry* strategy, evidently relies more on local and traditional knowledge in terms of soil management strategies (Hobo et al., 2020).

Openness to change is measured by assessing motivations for changes in farming strategies implemented in the last 10 years (e.g. technology and consumer demands), as well as ratings of knowledge gaps and openness to change (Dharmawan, 2001). Overall, both groups were equally responsive to changes and relatively quick to implement them with the aim of securing their livelihood. Farmers in rural Indonesia have been observed to be very open to market dynamics and consumer demand, and policy changes, aiming naturally for higher levels of income. In terms of risks and resilience, the experience of drought and water stress helps smallholders in Central Java to overcome adaptation barriers and implement more viable adaptation options in their farming strategy (Irham et al., 2018). The high adaptability of smallholders in the study population can also be detrimental to resilience goals. Over the last decades several regional developments of Central Javan areas from agroforestry to plantations at the cost of biodiversity and the provision of ecosystems goods and services while simultaneously heightening the vulnerability of the specialized livelihoods (Feintrenie et al., 2010).

A *shared vision* is an intangible asset that is theorized to help accelerate individual efforts in bringing about a positive change in the community (Barrios et al., 2020; Ota, Herbohn, et al., 2020; Rigg, 2006; Rosset & Martínez-Torres, 2012). This multiplicator effect was practically non-existent in the *Conventional* group but relevant in *Agroforestry*. This indicates the accelerating group dynamic needed to bring about change in the associated community. It conceptually coincides with a high level of reflection and shared learning and is thus closely related to the capacity for self-organisation (Ifejika Speranza et al., 2014).

6.2.3. Capacity for self-organisation

Capacity for self-organisation relates to a transformative element with a household system or community and depicts the ability of a household to engage in community activities, form structures, and norms and rules to the advantage of the individual livelihood and wellbeing of the community (Ifejika Speranza et al., 2014; Jacobi et al., 2018). *Agroforestry* scored by 15.3pp significantly higher in this category as compared to *Conventional*.

Institutions essentially are intended to depict relations of smallholders and their community groups and how these enable them to achieve better livelihood outcomes. *Agroforestry* smallholders had significantly more marketing power as 40% of them organised selling their produce as farmers group and were able to negotiate their prices together. This enables farmers to increase the profitability of their livelihood strategies. However, while similar effects are visible in Central Java (Mariyono, 2019a), present results do not suggest this effect has taken place yet.

Next, *cooperation and networks* is closely related to *social capital* as it includes reciprocity and trust which are important in post-disaster recovery (Aldrich, 2012; Utami et al., 2018). The sub-dimension essentially shows inter-group cooperation that can alternatively also be assigned to social capital. However, the proposed agro-ecological resilience indicator offers a more detailed differentiation that helps to take a closer look at sub-dimensions critical in times of disasters. The dimension differed only marginally between the identified strategies. Trust and savings/investment group participation was equally high in both groups and is a fundamental and important source for investments into more profitable farming strategies (Barral, 2018; Danai Manyumwa et al., 2018; Wood et al., 2014). This reflected in the equally high reciprocity ratio of receive-give, while borrowing-lending was higher in *Agroforestry*.

Self-sufficiency is an important aspect of household resilience, as it shows the ability to cope with market shocks or natural hazards. It also reflects decentralization of a system and independence of a household as essential capability to deal with crises when no outside support reaches the household (Ifejika Speranaza et al., 2014). Self-sufficiency was marginally higher in *Agroforestry* group. However, self-consumption of farm produce was 35 pp higher in *Agroforestry* hinting at the larger diversity of produce consumed of the household, while home-garden size did not differ significantly. This may be due to a difference in how the area is used and constitutes an important point in livelihood resilience, as a recent shift towards more mono-cropped home-gardens across SEA is visible (Abdoellah et al., 2020; Mitchell & Hanstad, 2004; Mohri et al., 2013; Suryanto et al., 2012). Interestingly, sufficiency of farm income was lower in the *Conventional* group underlining the high need for investment to sustain the potato crop.

Last, *political capital* as a measure of closeness of power to the community or household was significantly more developed in *Agroforestry*. The ability to introduce change in the community is important for all members so as to spread best-practice models and establish mutually beneficial cooperation above informal household to household agreements which often perish during systemic disasters (Utami et al., 2018). In this way for example, households or farmer's group can push for community organisations or accessing crop insurance as was the case for self-organisation in Cirebon Regency, Indonesia (Pratiwi et al., 2018). Similarly in the present study, while in Agroforestry half of all household heads benefited from health insurance, in conventional only 28.94% of household heads were insured (Proportion-test, mean-diff.=21.05 [0.111], p=0.0576).

6.3. Natural hazards and coping strategies

Finally, the third set of research questions investigated into hazards and coping strategies. Coping strategies follow from livelihood strategies and are based on livelihood outcomes; they are influenced by governing structures and processes, based on the natural resource base and are the first counter towards the vulnerability context and shocks and hazards (compare Ellis, 1998).

Central Java faces a variety of natural hazards that are increasingly exacerbated by climate change (Djalante, 2018; Djalante et al., 2017; Masson-Delmotte et al., 2018). Indonesia is particularly subject to precipitation variability induced by the El Nino Southern Oscillation (ENSO). The phenomenon and associated El Nino and La Nina events frequently cause drought, extreme precipitation and fierce winds/storms and affect food production, farm income and livelihood resilience (Keil et al., 2007; Measey, 2010; Naylor et al., 2007; Oktaviani et al., 2011; Syaukat, 2021).

Agroforestry households reported droughts, excess wetness, storms/fierce winds, closely followed by market shocks as most impactful disasters in the last five years which is in line with findings from uplands in Central Sulawesi (Iswoyo et al., 2019). The most often used positive coping strategies for *Agroforestry* were to increase crop input, the unspecified probing option *"resolve it on our own"* that signified a positive coping, change of the main crop and selling of assets such as trees and livestock. On the other hand, the most often negative coping strategies were the unspecified *"sitting it out"* signifying the inability to do something about the situation, using formal credit and early harvesting. Conversely, *Conventional* households reported excess wetness, price volatility and market shocks, as well as unspecified harvest failures. The most often used positive coping strategies for Conventional was to change the main crop, followed by increasing input and resolving it on their own. The most often used negative coping strategies were accessing informal credit, to sit it out or accessing formal credit. The findings on relevant hazards correspond to recent estimations about climate impact on smallholder livelihoods, where especially climate variability with prolonged droughts and extreme precipitation increase in frequency, duration and impact (Djalante, 2018; Djalante et al., 2017; Masson-Delmotte et al., 2018).

Keil et al., (2007) in their drought resilience assessment in central Sulawesi find that the possession of liquid assets (farm and household assets and goods that can be sold within a short time span), as well as access to credit and the level of technical efficiency in agriculture help farmers cope with drought in the short term. However, no distinguishment on the long-term consequences of short-term coping strategies is made. The present results correspond in several ways to these findings. First, livestock and trees can be counted as semi-liquid assets, allowing for a short period of mobilisation. This is preferable to reducing consumption or selling off necessary farm equipment that helps to stabilise the livelihood in the mid to long term. Moreover, evidence from South-East Asian uplands suggests that agroforestry systems had shorter recovery time after natural disasters due to their increased environmental and economic buffers and fruit trees that support household food security during lean periods (Lasco et al., 2014, 2016; Magcale-Macandog et al., 2010; Simelton et al., 2015).

Second, while credits are indeed able to buffer short-term income loss, long term consequences of debt can be crushing on households and make it difficult to regain or exceed former levels of livelihood outcomes. Third, in the case of drought resilience, the technical irrigation component can be regarded as key technology of technical efficiency in distinct cropping and social-ecological systems (Hussain et al., 2006). Cropping systems and their technical efficiency can thus not be regarded as independent of their production factors. Keeping a high level of technical efficiency of the respective cropping system while selling drought need specific irrigation related farm equipment are therefore antagonistic coping mechanism that reduce overall livelihood resilience. Only in the case of crops that are either not specifically affected by drought or weather extremes or can be preserved or stored so as not to be affected during the event is selling of assets a viable, yet still negative coping strategy.

Overall, households with higher calculated resilience were more likely to use positive coping strategies when countering shocks. Households following the *Conventional* strategy were less likely to employ positive coping strategies. The likelihood of applying a positive coping strategy is thus directly related to dimensions and sub-dimensions of resilience. Different income sources and high levels of farm diversity, heterogeneity of crops and breeds, the capacity to access services and trainings all contribute to a household's resilience capacity and capability to apply positive coping strategies.

7. Conclusion

The present research investigated farm incomes, livelihood resilience and coping mechanisms of two geographically rural communities and their associated farming strategies in the uplands of Central Java. Two distinct farming strategies were identified with different implications for natural resource management in the area. The *Agroforestry* group relied on a highly diversified crop-livestock system with agroforestry at different levels of integration and complementary off-farm income. The *Conventional* group followed an intensified cropping strategy that relied on few highly profitable crops, amongst which, the potato was the most important following the recent boom in SEA.

The findings supplement existing theoretical, conceptual, methodological, and empirical research on livelihood resilience in several ways. First, the *Agroforestry* group had higher livelihood resilience, was more likely to use positive coping strategies and was associated with less land degradation as compared to the *Conventional* group. Moreover, the *Agroforestry* strategy exhibited a higher benefit-cost ratio while per hectare farm profitability was higher in *Conventional*. However, the *Conventional* strategy used significantly higher levels of farm inputs and was associated with higher levels of land degradation. These findings are in line with a swath of other empirical work in the humid tropics that demonstrate the benefits of agroforestry systems for livelihoods and environment (Ota et al., 2020). Further, they answer to the need for more detailed agroeconomic analysis of agroforestry smallholder farms (Sinclair et al., 2019, p. 2).

Second, the research strengthens the used methodological approach by contributing to the further applicability of composite asset indicators in the context of livelihood resilience in several ways. As CAIs are, in principle, highly context dependent and, methodologically, a black box, generalisability is not given and their purpose is mostly limited for the indication of groups or the prevalence of latent concepts (Hinkel, 2011). However, within the research framework, sample population and geographical area, it is important to validate the indicator construct by drawing on other variables. The indicator was successfully validated by comparability of results with other agroforestry livelihood resilience studies and the association with stated well-being (compare Quandt, 2018). Moreover, by drawing on past hazards and coping experiences, the results suggest that higher levels of livelihood resilience increased the likelihood to apply positive coping strategies. Overall, these connotations suggest the internal and external validity of the indicator construct as delineated within the present geographical context.

Third, the present research contributes to the discourse surrounding livelihood resilience assessment by integrating two novel approaches that both draw on the SLF. Both, Quandt's (2018) HLRA and Ifejika Speranza et al.'s (2014) conceptualizations (with Jacobi et al.'s (2018) operationalization of livelihood resilience were merged, translated to a household level and expanded to the regional context of Central Java. This amalgamation and contextualization of livelihood indicators is at the same time a strength and weakness of the present approach. While it allows for detailed context specific assessment, results become incomparable across livelihood zones. This chronic incomparability is inherited from the underlying sustainable livelihood approach that fundamentally suffers from the same shortcoming (De Haan, 2012b; Scoones, 2015).

Fourth and last, the findings contribute to the understanding of the connection between agroforestry, resilience and coping. The implication of their conclusive connection strengthens the recent ecological intensification approaches in international development. Agroforestry can be integral to climate smart agricultural management approaches and form a nature-based solution to weather the effects of increased climate variability.

The present study has uncovered the connections between the implementation of agroforestry, increased livelihood resilience and the application of positive coping mechanisms. Several intersections between these concepts have been identified for further research. First, theoretically, conceptually and empirically, the role of formal and informal credits for consumption smoothing and strategic investments in needs further clarification in the context of anticipatory and adaptive capacity as well as coping behaviour of households (compare IFAD 2016 source). Further, the use of livestock as saving assets, and the profitability of their integration in crop and agroforestry systems may reveal synergies that provide viable alternatives to crop booms and associated dependencies and vulnerabilities (compare Irham et al., 2018). Third, the agroecological livelihood resilience indicator systems developed by Quandt (2018) and Ifejika Speranza (2014) offer an entry point into livelihoods that demands the development of a comprehensive conceptual and methodological integration of livelihood outcomes, strategies and systemic cross-scale interactions in the social-ecological systems. Fourth, Córdoba Vargas et al. (2020) stress the importance of incorporating structural socio-economic hysteresis and analysis of inequality in livelihood resilience assessment in agroecological systems and transitions; a need for further research that is highlighted by the results of the present work.

Overall, the research emphasizes how smallholders and the environment can profit from the implementation of agroforestry for a more sustainable and climate smart development. The results highlight the benefits of agroforestry for higher livelihood resilience towards climate change and market shocks, and a higher likelihood of applying positive coping strategies. However, technological, material and financial support is necessary to achieve lasting change.

8. References

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Appendix A: Survey Protocol

Farm Household Survey 2018

Name of the respondent: Place: Leksana / Penanggungan *(circle what applies)* RT: RW:
Code of respondent:

Name of the interviewer and RA: Date: Time:

A: General questions about household (HH)

A1. Household table

Please make a note on every child, even if not living in the house.

No	Status	Living in HH (Yes/No)	M/F	Age (years old) children in order of birth	Education (years) (if child, completed so far)***	(foreseen to have) Higher education than HH Head (Yes / No)	Working on farm? (Yes / No)	General health of family member (please rate 1-10) *	Do your health problems impact the ability to contribute to family income (please rate 1-10)**	Health Insurance (Yes / No)
1	HH head									
2										
3										
4										
5										
6										
7										
8										
9										
10										

**) 1 = very poor, 10 = very good;*

***) 1 = no impact, 10 = very high impact;*

****) TK = kindergarten; SD/MI/MIN = 1-6 grade/years; SMP/MTs = 7-9 grade/years;*
SMA/MA/MAN = 10-12 grade/years; S1 = bachelor degree (add 4 years);
S2 = master degree (add 2 years).

A2. How many generations have worked on this farm already? …………….

A3. What were the reasons for you to become a farmer? *(choose all that applies)*

1. Parents owned farm
2. Interest or special education in farming
3. No other job opportunity
4. Others *(please specify)*…………………………………….

A4. At what age did you start managing the farm? ……………

A5. Did you take over the farm from your parent? Yes / No

A6. What is the likelihood of at least one of your children to take over your farm?

1. Definitely	*100%*	If 1, 2 or 3, which child/which children?................. (*Refer to HH table)*
2. Very Probably	*80%*	
3. Probably	*60%*	
4. Possibly	*40%*	
5. Probably Not	*20%*	
6. Definitely Not	*0%*	

A7. Do you plan to share your farmland between your children? Yes / No

A8. If your children will not take over the farm, what will you do?
(Only ask if there is not already a successor. Choose all that apply)

1. Find an external successor
2. Sell/rent the land
3. Leave the land fallow
4. Not decided yet
5. Split the land between my children
6. Other *(please specify)*…………………….

A9. Who do you talk with when you have to make a decision regarding **<u>the way</u>** you farm?

First ………………………………………………………….

Second ………………………………………………………….

Third ………………………………………………………….

A10. What are your investment priorities?
(*Explain investment in your own words if needed. Please rank the 3 most important ones from 1-3)*

( ) 1. Education for me and/or my children
( ) 2. Assets for my household
( ) 3. Assets for the farm
( ) 4. Land
( ) 5. Other *(please specify)* ……………………….

B: Land related questions

B1. Land Holding

Status	Arable land	Homegarden	Other (e.g. Forest / Grassland / …)	Total
Self-owned (m2)				
Owned for how many generations				
Rented (m2)				
Rented from whom *(options 1 to 5)*				
Rent paid (IDR/year)				
Rented out (m2)				
Rented to whom *(options 1 to 5)* *				
Rent received (IDR/year)				
Sharecropping (m2)				
Share of return (%)				
Share of input (%)				
Previous land use				
For how long in agricultural use				

***)** *1 = Relative inside village 2 = Relative outside village 3 = Neighbor or community member 4 = Village 5 = Others (please specify)*

B2. Do you practice agroforestry? Yes / No

If yes, on what approximate percentage of your total farm area? …………%

B3. Why do you, or why do you not, practice agroforestry?

……………………………………………………………………………………………………
……………………………………………………………………………………………………

C1. Crop Rotation (only for rented and managed land)

Plant Planning Pattern *(please state the type of plant and its varieties, both seasonal and annual crops i.e. including trees)*

Fields / Plots	Year											
	2018							2017				
	Month											
	Jul	Jun	May	Apr	Mar	Feb	Jan	Dec	Nov	Oct	Sep	Aug
Total land (arable, homegarden, grass, forest, …)												
1												
2												
3												
4												
5												
6												

C2. Seasonal Crops (during the last 12 months)

N.	Crop	Planting area (m^2)	Number of harvests per year	Amount per Harvest (kg)	Fertilizers*	
					Organic (e.g. manure) Kg per season/year (*circle one*)	Chemical (e.g. NPK) Kg per season/year (*circle one*)
1						
2						
3						
4						
5						
6						
7						

*Note: *) please ask and identify with "S" if fertilizers, and pesticides are made or produced by the household*

Crop	Pesticides*									
	Type I (Name / kg)	Type II (Name / Kg)	Type III (Name / Kg)	Type of application **	Where do you apply ***	When do you apply ****	Is the soil covered *****	n of applications in the previous season		Vulnerability to pest *(tick if applicable)*
1										
2										
3										
4										
5										
6										
7										

***) 1 = Spraying 2 = Granulates 3 = Pool irrigation 4 = Pool spraying*
****) 1 = Soil 2 = Leaves   3 = Fruit 4 = All*
*****) 1 = Prevention 2 = Treatment / control*
******) 1 = Plastic 2 = Organic mulching 3= No*

C3. Annual Crops

N.	Crop	Planting area (m^2)	Number of harvests per year	Amount per Harvest (kg)	Fertilizers*	
					Organic (e.g. manure) Kg per season/year (*circle one*)	Chemical (e.g. NPK) Kg per season/year (*circle one*)
1						
2						
3						
4						
5						
6						
7						

*Note: *) please ask and identify with "S" if fertilizers, and pesticides are made or produced by the household*

Crop	Pesticides*									
	Type I (Name / kg)	Type II (Name / Kg)	Type III (Name / Kg)	Type of application **	Where do you apply ***	When do you apply ****	Is the soil covered *****	n of applications in the previous season		Vulnerability to pest (*tick if applicable)*
1										
2										
3										
4										
5										
6										
7										

***) 1 = Spraying 2 = Granulates 3 = Pool irrigation 4 = Pool spraying*
****) 1 = Soil 2 = Leaves 3 = Fruit 4 = All*
*****) 1 = Prevention 2 = Treatment / control*
******) 1 = Plastic 2 = Organic mulching 3= No*

C4. Which are the three most frequent tree species on your land?

Tree species	% of total trees on farm	Use(s) *(circle what is applicable)*	Positive impact on soil fertility?
	……… %	Timber / Fuel wood / Forage / Fruits	Yes / No / Unclear / Do not know
	……… %	Timber / Fuel wood / Forage / Fruits	Yes / No / Unclear / Do not know
	……… %	Timber / Fuel wood / Forage / Fruits	Yes / No / Unclear / Do not know

D. Pesticides

D1. From where do you get the pesticides?

1. Farmer´s shops
2. Traders/promoters
3. Government
4. Others (*please specify*)…………………………..

D2. Do you have problems with your soil? Yes / No

If yes, which? (*Choose all that applies)*

1. Landslides:
2. Erosion:
3. Infertility:
4. Others: *(specify)*…………………….

D3. What percentage of your fields is located on slopes?
……… %

D4. Are you using any of the following strategies ? *(choose all that applies)*

1. Terraces in steep slopes
2. Contour farming
3. Intercropping / multi-cropping
4. Crop rotation
5. Adding manure
6. Natural mulching
7. Plastic covering
8. Agroforestry
9. Soil bounds (trees, stones)
10. Other: *(specify)*……………………

D5. What irrigation system do you have on your farm? (*choose all that applies*)

1. Rainfed
2. Simple water supply (no concrete canals)
3. Semi-technical (concrete canals)
4. Technical (concrete canals with water gates, on-field distribution pumps)

E. Economics

E1. Can you easily access credits, either informal Yes / No

(e.g. relatives, neighbours/friends, community groups*)*

or formal (e.g. banks)? Yes /No

E2. Which credit source would you prefer?
(Please rate from (1) as the most preferable to (5) as the most unpreferable)

(....) relatives (....) neighbors/friends (....) community groups

(....) banks (....) others ....

E3. How much agricultural inputs subsidies did you receive in the last year? *(Please note all other fertilizers received)*

Seeds: .... kg; Urea: .... kg; NPK: ....kg;
Seedlings: ………pieces; Pesticides: .... bottle/sachet Cash: ……… (IDR)
Price discount: Yes / No; If Yes, on…………..….... Other: ....

E4. How do you sell your products individual or as a group?

1. Direct contract (as individual)
2. Traders (as individual)
3. Direct contract (as farmer group)
4. Traders (as farmer group)

E5. Can you negotiate the price?
Yes / No

F. Household resilience and access to infrastructure

F1. What is the major risk faced by your Household/farm? *Choose one!*

1. Natural hazards and phenomena *(climate change effects, pests, volcano etc.)*
2. Fluctuation of prices and other market risks
3. Political/institutional risks
4. Personal/family risks *(health, succession…)*
5. Others (specify) ……………………………...

F2. Which weather related hazard or other shock affected your household the most in the past? *(e.g., landslide, fierce winds, earthquake, harvest failure, serious sickness, price volatility, etc.)*

………

F3. What did your household do to cope with the weather related hazard or other shock *(as mentioned above)*?

…………………………………………………………………………………………………… ………

Possible options for probing only:

a. *Resolve it by ourselves (in the household and or in the community)*
b. *Asking for help from relatives/neighbours/friends in the community*
c. *Asking for help from relatives/neighbours/friends outside the community*
d. *Asking for help from the local government*
e. *Access informal or formal credits (please explain)*
f. *Sitting it out*

F4. How high do you think is the capability of your household to **withstand** future hazard or shock? …….. (*Dari pengalaman tersebut*), *seberapa kuat kapasitas/kemampuan rumah tangga Anda untuk **menahan dan pulih kembali** dari goncangan atau bencana (yang mungkin terjadi) di masa depan?*

1 Very weak to 10 Very strong

F5. How do you rate your current overall living conditions and wellbeing compared to the average household in your community ?

1 Much better 2 Better 3 Slightly Better
4 Slightly Worse 5 Worse 6 Much worse

F6. Do you have easy access to: a) Irrigation water: Yes/No b) Household water: Yes/No

G. Community Groups

G1. Which community groups do you and other household members join in this community (including farmers group)? *(please connect name of the group with eventual role)*

Community Group(s)	Regularity of meetings (x times per week/month/year - *specify*)	Regularity of attendance (x times per week/month/year - *specify*)	Role(s)*

**) 1 = Member, 2= Leader, 3 = Secretary, 4 = Treasurer, 5= Other*

G2. Do you think that you can rely on community groups in times of weather-related disaster or other shock? Yes / No

In which way? *(Choose all that applies)*

a) moral support b) cash c) donations in goods d) mutual help *(e.g. rebuilding house)*

G3. Have you participated in a IPM (Integrated Pest Management) Farmer Field School ? Yes / No

H. Political Capital

H1. When you have an idea to change something in your community, to whom would you likely go ? *(Please rate with number 1-6, from the most likely to go to (1) to the least likely to go to (6))*

(....) Neighbors/friends/relatives in this community

(....) Community leaders (i.e. hamlet head, RW/RT head)

(....) Community groups meeting

(....) Sub-district and Village Office

(....) Government officials/offices (*please specify)*...

(....) Others (*please specify)*………………………………….

H2. Who (e.g. individual person, institution or community group) holds the most influence in this community (e.g. so that any idea to change something will be realized by his/her influence)?

....
....

I. Cultural capital & Traditional Ecological Knowledge

I1. Times a week you do consume meals without rice (3 meals a day / 21 Meals a week): ....

I2. What percentage of your food consumption is supplied by your farm ? *(per year)* ....……… %

J. Changes in farming practices

J1.

Thinking back for 10 years, have there been any … that made you change the way you farm?	If yes, What were these ?	How did you change your farming?
State interventions *e.g. laws, government policies, financial support*		
New technologies *e.g. machine, pesticide, mobile phone*		
Major changes in what people want to buy from farmers *e.g. visually attractive products, organic food, agrotourism*		
Farmer education *e.g. farmer field schools, participatory research projects*		
Changes in your culture *e.g. beliefs, attitudes, role expectations, traditions*		

K. Statements

Please read out the statement and choose the level of agreement from 1- 6, where ***1 = completely agree, 2 = mostly agree, 3 = slightly agree, 4 = slightly disagree, 5 = mostly disagree, 6 = completely disagree****!*

	Statement	1	2	3	4	5	6
1	"As a farmer I feel appreciated and respected in my job by the society" "*Sebagai seorang petani, saya merasa dihargai dan dihormati dalam pekerjaan saya oleh masyarakat*"						
2	"The risks and obstacles for farmers are getting higher every year" "Risiko-risiko dan hambatan-hambatan yang dihadapi petani makin tinggi tiap tahunnya"						
3	"In the future I will need external help to maintain my Household/farm" *(government, financial support, further education…)* *"Di masa depan, saya akan membutuhkan bantuan untuk mempertahankan rumah tangga tani saya"*						
4	"I need more knowledge in order to be a successful farmer in the future" "*Saya perlu pengetahuan lebih untuk menjadi petani sukses di masa depan*"						
5	"The future of my farm concerns me" "*Masa depan usahatani saya menjadi perhatian saya*"						
6	"I´m worried about the future of my farm because of soil related problems" "*Saya khawatir mengenai masa depan usahatani saya karena masalah-masalah terkait tanah di lahan saya*"						
7	"For the next generation, there are better professional options then becoming a farmer" "*Untuk generasi mendatang, tersedia pilihan-pilihan profesional yang lebih baik daripada menjadi petani*"						
8	"My income from farming is enough to provide for me and my family" "*Pendapatan saya dari bertani cukup untuk memenuhi kebutuhan saya dan keluarga*"						
9	"The average age of the farmers in my community is getting older and older" "*Rata-rata umur petani di masyarakat (desa) saya semakin tua dan tua*"						
10	"Young people in my community are not interested in becoming a farmer anymore" "*Para pemuda di masyarakat saya tidak lagi tertarik menjadi petani*"						
11	"Pesticides affect the health of me and my family in a negative way" "*Pestisida mempengaruhi kesehatan saya dan keluarga secara negatif*"						
12	"The soil from my field is easy to plow" "*Tanah di lahan saya mudah dibajak*"						
13	"I am open to changing my farming practices" "*Saya terbuka terhadap perubahan cara-cara budidaya pertanian saya*"						

Please read out the statement and choose the level of agreement from 1- 6, where ***1 = completely agree, 2 = mostly agree, 3 = slightly agree, 4 = slightly disagree, 5 = mostly disagree, 6 = completely disagree****!*

	Statement	1	2	3	4	5	6
14	"My soil is highly polluted with pesticides" "*Tanah di lahan saya sangat tercemari oleh pestisida*"						
	"My household has easy access to roads in good condition, which connect us easily to … "*Rumah tangga saya punya akses yang mudah ke jalan dengan kondisi yang bagus, yang menghubungkan kami dengan mudah ke…*						
15	…Market" *… pasar"*						
16	…Retailer" *…pedagang"*						
17	…Hospital" *…rumah sakit"*						
18	…School" *…sekolah"*						
19	"The roads in our area are heavily affected by natural hazards (e.g. damaged by heavy rain, landslides, soil erosion, etc.)" "*Kondisi jalan di wilayah kami sangat dipengaruhi oleh ancaman-ancaman bahaya alam (misalnya, rusak karena hujan deras, tanah longsor, erosi tanah, dll.)*"						

L. Reciprocity and trust

L1. What is the frequency of giving and receiving of physical goods between your household and neighbors/friends/relatives in this community?

On average, your family giving: .... times/week/month/year *(circle what applies)*

Your family receives: .... times/week/month/year *(circle what applies)*

L2. What is the frequency of borrowing and lending cash between your household and neighbors/friends/relatives in this community?

In one year average, your family borrows: .... times/year

your family lends: .... times/year

L3. "This community trusts each other in the matter of borrowing and lending cash"

1. Full trust
2. Very trustful
3. Somewhat trustful
4. Untrustful
5. very untrustful
6. No trust

Appendix B: Supplementary tables

Sud-dimension association tables

Buffer capacity – subdimension association tables

Table B 1: Natural capital - association between variables

	Natural capital (Kendall's tau)	1	2	3	4	5
1	Land ownership [yes/no]	1				
2	Soil condition [scale, 1-6=worst]	0.1887	1			
		0.1053				
3	Soil physical condition [scale, 1-6=worst]	-0.0555	0.2194	1		
		0.6581	0.0472			
4	Soil on slopes [%] (to inverse)	-0.0719	-0.1905	0.0901	1	
		0.5147	0.0544	0.3838		
5	Soil related problems [0-4])	-0.1793	-0.396	0.1124	0.1888	1
		0.14	0.0003	0.3307	0.067	

Table B 2: Physical capital - association between variables

	Physical capital (Kendall's tau)	1	2	3	4	5
1	Road system connection to infrastructure [scale 1-6=worst]	1				
2	Road conditions during wet season [scale 1-6=worst])	0.1952	1			
		0.0345				
3	Easy access to irrigation water [yes/no]	-0.2055	-0.0151	1		
		0.0424	0.8912			
4	Easy access to household water [yes/no]	-0.0469	0.1576	0.3245	1	
		0.6464	0.1363	0.0051		
5	Technical level of irrigation system [1-4]	-0.4768	-0.1471	0.405	0.2721	1
		0	0.1337	0.0002	0.0113	

Table B 3:Social capital - association between variables

	Social capital (Kendall's tau)	1	2	3
1	Community group support [rating, 0-4]	1		
2	Community groups - excluding farmers group and savings group [count]	0.2997	1	
		0.0017		
3	Participation in community groups [percentage]	0.0347	0.3663	1
		0.7251	0.0002	

Table B 4: Financial capital - association between variables

	Financial capital (Kendall's tau)	1	2	3	4	5	6
1	Access to formal and informal credits [1=one source, 2=both sources]	1					
2	Livestock ownership [TLU]	-0.1164	1				
		0.2397					
3	Size of operated farmland [ha]	0.2004	-0.0449	1			
		0.0304	0.5967				
4	Farm equipment [count]	0.0702	0.0785	0.1805	1		
		0.4644	0.3686	0.0271			
5	Income diversification (1/simpson)	-0.0482	0.2565	-0.2892	-0.0838	1	
		0.6049	0.0023	0.0003	0.3051		
6	Income in household [Mio IDR/pc*month]	0.1032	-0.0639	0.1962	0.0523	-0.159	1
		0.2606	0.4456	0.0122	0.5194	0.0421	

Table B 5: Farm diversification - association between variables

	Farm diversification (Kendall's tau)	1	2	3	4		Farm diversification (Spearman's rho)	1	2	3	4
1	Crop diversity (1/Simpson)	1				1	Crop diversity (1/Simpson)	1			
2	Livestock diversity (1/Simpson)	0.3468	1			2	Livestock diversity (1/Simpson)	0.47	1		
		0						0			
3	Total number of crops planted (n)	0.3724	0.3346	1		3	Total number of crops planted (n)	0.5012	0.4376	1	
		0	0.0002					0	0.0001		
4	Agroforestry share of area (%)	0.4093	0.5157	0.4934	1	4	Agroforestry share of area (%)	0.5528	0.6275	0.6396	1
		0	0	0				0	0	0	

Table B 6: Human capital - association between variables

	Human capital (Kendall's tau)	1	2	3	4	5
1	General health of family [scale 1-10]	1				
2	Dependency ratio [Percentage]	0.0915	1			
		0.3005				
3	Education of household head [years]	0.0211	0.1733	1		
		0.8378	0.0787			
4	most educated member variable	-0.083	-0.1784	0.1737	1	
		0.3687	0.0501	0.0914		
5	Household size	0.113	0.0868	0.0785	0.0885	1
		0.2134	0.3347	0.4413	0.3461	

Capacity for learning and adaptation – subdimension correlation tables

Table B 7: Knowledge of threats and opportunities - association between variables

Knowledge of threats and opportunities (Kendall's tau)		1	2	3	4
1	Extension service present [yes/no]	1			
2	Participation in government program [yes/no]	0.4617	1		
		0.0001			
3	Knowledge of an appropriate coping mechanism [yes/no]	-0.1209	0.0307	1	
		0.2924	0.7946		
4	Knowledge of a potential shock [yes/no]	0.0456	-0.0523	0.3451	1
		0.6974	0.6552	0.0026	

Table B 8: Cooperation and Networks - association between variables

Cooperation & networks (Kendall's tau)		1	2	3
1	Received any kind of training recently - excluding government or extension service [yes/no]	1		
2	Indicated learning from neighbours [yes/no]	0.162	1	
		0.1576		
3	Participation in Farmers Group [Percentage]	0.2151	0.0658	1
		0.053	0.5579	

Table B 9: Openess to change - association between variables

Openness to change (Kendall's tau)		1	2	3	4
1	Openness to technology [yes/no]	1			
2	Openness to consumer demands [yes/no]	0.3929	1		
		0.0006			
3	Understanding knowledge gaps [Likert scale, 1-6]	-0.2901	-0.147	1	
		0.0102	0.1941		
4	Openness to change [Likert, 1-6]	-0.3089	-0.2547	0.5203	1
		0.0046	0.0195	0	

Openness to change (Spearman's rho)		1	2	3	4
1	Openness to technology [yes/no]	1			
2	Openness to consumer demands [yes/no]	0.3929	1		
		0.0004			
3	Understanding knowledge gaps [Likert scale, 1-6]	-0.2936	-0.1488	1	
		0.0091	0.1937		
4	Openness to change [Likert, 1-6]	-0.3236	-0.2669	0.5451	1
		0.0039	0.0182	0	

Table B 10: Functioning feedback mechanisms - association between variables

Functioning feedback mechanisms (Kendall's tau)		1	2	3	4
1	Received subsidies in the past year [yes/no]	1			
2	Community group help in times of disaster [yes/no]	0.1633	1		
		0.1544			
3	IPM participation [yes/no]	0.1868	-0.0266	1	
		0.1025	0.823		
4	Social security [yes/no]	0.0852	0.0667	0.1737	1
		0.4585	0.5643	0.1292	

Table B 11: Traditional ecological knowledge - association between variables

Local traditional ecological knowledge (Kendall's tau)		1	2	3		Local traditional knowledge	1	2	3
1	Soil management strategies [count]	1			1	Soil management strategies [count]	1		
2	Applies mixed cropping/agroforestry? [yes/no]	0.5786	1		2	Applies mixed cropping/agroforestry? [yes/no]	0.654	1	
		0					0		
3	Weekly meals without rice [Percentage]	0.1189	0.0934	1	3	Weekly meals without rice [Percentage]	0.144	0.1043	1
		0.1901	0.3632				0.2085	0.3637	

Table B 12: Shared vision - association between variables

Shared vision (Kendall's tau)		1	2	3
1	Extension service present [yes/no]	1		
2	Participation in government program [yes/no]	0.4617	1	
		0.0001		
3	Indicated learning from neighbours [yes/no]	0.082	0.1777	1
		0.4766	0.1211	

Capacity for self-organisation – subdimension correlation tables

Table B 13: Institutions - association between variables

Institutions (Kendall's tau)		1	2	3
1	Marketing [scale, 1-4]	1		
2	Negotiation [yes/no]	-0.1261	1	
		0.2545		
3	Farmers group membership [yes/no]	0.1876	-0.1093	1
		0.089	0.3418	

Table B 14: Cooperation and networks - association between variables

Cooperation and Networks (Kendall's tau)		1	2	3	4
1	Trust [Likert scale, 1-6]	1			
2	Savings/Investment group participation [ratio]	0.0115	1		
		0.9181			
3	Reciprocity in goods [ratio]	0.07	0.0152	1	
		0.4688	0.8794		
4	Reciprocity in currency [ratio]	0.1142	-0.0653	0.141	1
		0.2323	0.5011	0.1061	

Table B 15: Self sufficiency of farming - association between variables

Self-sufficiency of farming (Kendall's tau)		1	2	3
1	Self consumption of production [Percentage]	1		
2	Farm income sufficiency [Likert, 1-6]	0.2153	1	
		0.0169		
3	Homegarden [m2]	0.1322	0.0125	1
		0.1036	0.8915	

Table B 16: Political capital - association between variables

Political capital (Kendall's tau)		1	2	3
1	Political power: Neighbours/friends/relatives [rating, 1-6]	1		
2	Political power: Community leaders [rating, 1-6]	-0.0491	1	
		0.6345		
3	Political power: Community group meetings [rating, 1-6]	0.0402	0.0474	1
		0.701	0.6461	

Resilience dimensions – variable test results

Table B 17: Buffer capacity - variable test results

Buffer capacity	Agroforestry				Conventional				T-test/Proportion-test			Ranksum			Quantile regression at p_50			Hodges Lehmann median difference		
	mean	sd	p50	iqr	mean	sd	p50	iqr	Mean-diff.	se	p	U	P	p	Median-diff.	se	p	Median-diff.	[95% Conf. Interval]	
Natural Capital																				
Land ownership [yes/no]	1.000	0.000	1.000	0.000	0.868	0.343	1.000	0.000	0.125	0.055	0.024									
Soil condition [scale, 1-6=best]	2.650	1.642	2.000	3.000	2.000	1.315	2.000	1.000				577.000	0.620	0.054	0.000	0.367	1.000	0.000	0.000	1.000
Soil physical condition [scale, 1-6=best]	1.650	1.145	1.000	1.000	1.763	0.786	2.000	1.000				626.500	0.412	0.138	1.000	0.000	0.000	0.000	-1.000	0.000
Soil on slopes [%]	0.512	0.307	0.500	0.450	0.513	0.364	0.500	0.800	-0.001	0.076	0.987									
Soil related problems [0-4]	0.600	0.810	0.000	1.000	1.080	0.277	1.000	0.000				271.500	0.272	0.000	1.000	0.000	0.000	-1.000	-1.000	0.000
Physical capital and infrastructure																				
Road system connection to infrastructure [scale 1-6=worst]	2.013	0.997	2.000	1.250	1.783	0.822	1.750	1.500				647.500	0.547	0.252	-0.250	0.300	0.407	0.000	-1.000	0.000
Road conditions during wet season [yes/no]	2.175	1.583	1.500	1.500	3.026	1.966	2.000	4.000				574.000	0.378	0.051	0.000	0.419	1.000	0.000	-1.000	0.000
Easy access to irrigation water [yes/no]	0.675	0.474	1.000	1.000	0.947	0.226	1.000	0.000	-0.272	0.089	0.002									
Easy access to household water [yes/no]	0.500	0.506	0.500	1.000	0.974	0.162	1.000	0.000	-0.474	0.100	0.000									
Technical level of irrigation system [1-4]	1.947	1.114	2.000	2.000	2.579	1.056	2.000	2.000	-0.632	0.249	0.013									
Social capital																				
Community group support [rating, 0-4]	2.125	1.399	2.000	3.000	2.263	1.309	2.000	3.000	-0.138	0.307	0.654									
Community groups – excl. farmers and savings group [count]	1.050	0.904	1.000	0.500	1.895	0.831	2.000	1.000	-0.845	0.197	0.654									
Participation in community groups [percentage]	0.682	0.439	1.000	1.000	1.009	0.290	1.000	0.000				483.500	0.318	0.001	0.000			0.000	-0.250	0.000
Human capital																				
General health of family [scale 1-10]	9.126	1.028	9.583	1.657	9.496	0.661	9.833	1.000				632.500	0.416	0.181	0.333	0.206	0.110	0.000	-0.500	0.000
Dependency ratio [Percentage]	0.467	0.536	0.333	0.375	0.522	0.404	0.500	0.467				646.000	0.425	0.248	0.167	0.090	0.068	-0.067	-0.250	0.000
Education of hh.-head [years]	6.125	1.042	6.000	0.000	6.237	1.618	6.000	0.000	-0.093	0.307	0.762									
Most educated member [years]	9.375	2.168	9.000	0.500	8.447	2.345	9.000	3.000				585.500	0.615	0.063	0.000	0.558	1.000	0.000	0.000	2.000
Household size	3.975	1.050	4.000	2.000	4.605	1.462	5.000	3.000	-0.858	0.277	0.003									
Financial capital																				

Buffer capacity	Agroforestry				Conventional				T-test/Proportion-test			Ranksum			Quantile regression at p_50			Hodges Lehmann median difference		
	mean	sd	p50	iqr	mean	sd	p50	iqr	Mean-diff.	se	p	U	P	p	Median-diff.	se	p	Median-diff.	[95% Conf. Interval]	
Access to formal and informal credits [1=one source, 2=both sources]	1.325	0.656	1.000	1.000	1.579	0.552	2.000	1.000				604.500	0.398	0.080	1.000	0.000	0.000	0.000	-1.000	0.000
Livestock ownership [TLU]	0.849	0.776	0.715	1.245	0.160	0.413	0.000	0.000				245.000	0.839	0.000	-0.730	0.079	0.000	0.700	0.390	0.820
Size of operated farmland [ha]	0.807	0.474	0.750	0.556	0.989	0.849	0.750	1.060				730.000	0.480	0.764	0.000	0.170	1.000	-0.040	-0.333	0.210
Farm equipment [count]	7.575	3.441	7.000	5.500	7.368	3.620	6.000	5.000				704.500	0.537	0.576	-1.000	1.094	0.364	0.000	-1.000	2.000
Income diversification (1/Simpson)	1.051	0.414	1.040	0.749	0.731	0.300	0.615	0.471				385.000	0.747	0.000	-0.441	0.158	0.000	0.304	0.144	0.513
Income in household [Mio IDR/pc*month]	1.468	2.032	1.093	0.586	2.191	2.653	1.229	1.602				604.000	0.397	0.119	0.176	0.237	0.460	-0.259	-0.730	0.055
Farm diversification																				
Crop diversity (1/Simpson)	2.745	0.855	2.895	1.055	1.418	0.713	1.340	0.553				181.000	0.881	0.000	-1.481	0.195	0.000	1.373	1.014	1.714
Livestock diversity (1/Simpson)	1.122	0.588	1.064	0.468	0.166	0.391	0.000	0.000				190.500	0.875	0.000	-1.086	0.043	0.000	1.000	1.000	1.157
Total number of crops planted (n)	8.450	3.843	8.000	5.500	4.368	2.398	4.000	2.000				244.000	0.839	0.000	-4.000	1.001	0.000	4.000	2.000	5.000
Agroforestry share of area (%)	68.750	34.803	100.000	70.000	1.711	3.813	0.000	0.000				1520.000	1.000	0.000	100.000	0.000	0.000	88.000	40.000	100.000

Table B 18: Capacity of learning and adaptation - variable test results

Capacity for learning and adaptation	Agroforestry				Conventional				T-test/Proportiontest			Ranksum			Quantile regression at p_50			Hodges Lehmann median difference		
	mean	sd	p50	iqr	mean	sd	p50	iqr	Mean-diff.	se	p	U	P	p	Median-diff.	se	p	Median-diff.	95% Conf. Interval	
Knowledge of threats and opportunities																				
Extension service present [yes/no]	0.925	0.267	1.000	0.000	0.026	0.162	0.000	0.000	0.899	0.113	0.113									
Participation in government program [yes/no]	0.525	0.506	1.000	1.000	0.079	0.273	0.000	0.000	0.446	0.105	0.000									
Knowledge of an appropriate coping mechanism [yes/no]	0.850	0.362	1.000	0.000	0.868	0.343	1.000	0.000	-0.018	0.079	0.815									
Knowledge of a potential shock [yes/no]	0.950	0.221	1.000	0.000	0.921	0.273	1.000	0.000	0.029	0.055	0.602									
Cooperation & networks																				
Reflective and shared learning																				
Received any kind of training recently – exc. government or extension service [yes/no]	0.500	0.506	0.500	1.000	0.289	0.460	0.000	1.000	0.211	0.111	0.058									
Indicated learning from neighbours [yes/no]	0.225	0.423	0.000	0.000	0.079	0.273	0.000	0.000	0.146	0.082	0.074									
Participation in Farmers Group [Percentage]	0.946	0.221	1.000	0.000	0.320	0.449	0.000	1.000	0.626	0.081	0.000									
Openness to change																				
Openness to technology [yes/no]	0.750	0.439	1.000	0.500	0.658	0.481	1.000	1.000	0.092	0.103	0.373									
Openness to consumer demands [yes/no]	0.800	0.405	1.000	0.000	0.684	0.471	1.000	1.000	0.116	0.099	0.242									
Understanding knowledge gaps [Likert scale, 1-6]	1.525	1.037	1.000	1.000	1.474	0.506	1.000	1.000				746.000	0.491	0.816	0.000			0.000	0.000	0.000
Openness to change [Likert, 1-6]	1.825	1.394	1.000	1.000	1.658	0.745	2.000	1.000				738.000	0.514	0.604	1.000	0.286	0.010	0.000	0.000	0.000
Functioning feedback mechanisms																				
Received subsidies in the past year [yes/no]	0.650	0.483	1.000	1.000	0.368	0.489	0.000	1.000	0.282	0.113	0.013									
Community group help in times of disaster [yes/no]	0.825	0.385	1.000	0.000	0.921	0.273	1.000	0.000	-0.096	0.076	0.205									
IPM participation [yes/no]	0.425	0.501	0.000	1.000	0.105	0.311	0.000	0.000	0.320	0.100	0.002									
Social security [yes/no]	0.475	0.506	0.000	1.000	0.289	0.460	0.000	1.000	0.186	0.110	0.092									
Local traditional knowledge																				
Soil-management strategies [count]	6.450	1.131	7.000	1.000	4.474	1.447	4.000	2.000	1.976	0.295	0.000									

Capacity for learning and adaptation	Agroforestry				Conventional				T-test/Proportiontest			Ranksum			Quantile regression at p_50			Hodges Lehmann median difference		
	mean	sd	p50	iqr	mean	sd	p50	iqr	Mean-diff.	se	p	U	P	p	Median-diff.	se	p	Median-diff.	95% Conf. Interval	
Applies mixed cropping/agroforestry? [yes/no]	1.000	0.000	1.000	0.000	0.237	0.431	0.000	0.000	0.763	0.109	0.000									
Weekly meals without rice [Percentage]	6.775	7.109	4.500	15.000	3.263	5.371	0.000	6.000				558.500	0.633	0.033	-6.000	2.185	0.000	2.000	0.000	6.000
Shared vision																				
Extension service present [yes/no]	0.925	0.267	1.000	0.000	0.026	0.162	0.000	0.000	0.899	0.113	0.000									
Participation in government program [yes/no]	0.525	0.506	1.000	1.000	0.079	0.273	0.000	0.000	0.446	0.105	0.000									
Indicated learning from neighbours [yes/no]	0.200	0.405	0.000	0.000	0.105	0.311	0.000	0.000	0.095	0.082	0.246									

Table B 19: Capacity for self-organisation - variable test results

Capacity for self-organisation	Agroforestry				Conventional				T-test/Proportiontest			Ranksum			Quantile regression at p_50			Hodges Lehmann median difference		
	mean	sd	p50	iqr	mean	sd	p50	iqr	Mean-diff.	se	p	U	P	p	Median-diff.	se	p	Median-diff.	95% Conf. Interval	
Institutions																				
Marketing [scale, 1-4]	2.700	1.114	2.000	2.000	1.842	0.370	2.000	0.000	0.000			460.000	0.697	0.000	0.000			0.000	0.000	2.000
Negotiation [yes/no]	0.775	0.423	1.000	0.000	0.921	0.273	1.000	0.000	-0.146	0.082	0.074									
Farmers group membership [yes/no]	1.000	0.000	1.000	0.000	0.421	0.500	0.000	1.000	0.579	0.102	0.000									
Cooperation and networks																				
Trust [Likert, 1=worst to 6=best]	5.375	0.868	6.000	1.500	5.526	0.725	6.000	1.000				707.500	0.465	0.538				0.000	0.000	0.000
Savings/Investment group participation [ratio]	0.619	0.477	1.000	1.000	0.324	0.462	0.000	1.000	0.295	0.106	0.007									
Reciprocity in goods [ratio]	0.908	0.629	1.000	0.400	0.896	0.771	1.000	0.520				711.000	0.532	0.610	0.000	0.158	1.000	0.000	0.000	0.333
Reciprocity in currency [ratio]	1.523	4.133	0.600	1.000	1.198	1.170	1.000	1.444				577.000	0.380	0.063	0.400	0.254	0.120	-0.354	-0.900	0.000
Self-sufficiency of farming																				
Self consumption of production [Percentage]	49.200	29.667	50.000	52.500	17.368	14.229	12.500	25.000				313.000	0.794	0.000	-35.000	13.171	0.010	35.000	20.000	48.000
Farm income sufficiency [Likert, 1-6]	2.675	1.457	2.000	2.000	1.711	0.732	2.000	1.000				460.500	0.697	0.000	0.000	0.289	1.000	1.000	0.000	1.000
Homegarden [m2]	205.550	335.925	127.500	225.000	162.711	188.734	124.000	179.000				746.500	0.509	0.892	-7.000	49.509	0.888	0.000	-50.000	66.000
Political capital																				
Political power: Neighbours/friends/relatives [rating, 1-6]	2.500	2.124	1.000	3.500	3.000	2.360	1.500	5.000				683.000	0.449	0.394	1.000	0.421	0.020	0.000	0.000	0.000
Political power: Community leaders [rating, 1-6]	2.667	2.094	2.000	5.000	3.816	2.392	6.000	5.000				568.500	0.384	0.060	4.000	0.463	0.000	0.000	-3.000	0.000
Political power: Community group meetings [rating, 1-6]	1.975	1.790	1.000	1.500	2.816	2.300	1.000	5.000				598.000	0.393	0.060	0.000			0.000	-1.000	0.000

Validation: Association between resilience dimensions and measures of wellbeing and resilience

Table B 20: Measures of association for resilience dimensions and subjective measures of wellbeing and resilience

		Sample							Agroforestry							Conventional					
	Variables	1	2	3	4	5	6	Vars.	1	2	3	4	5	6	Vars.	1	2	3	4	5	6
1	Resilience (calculated)	1.000						1	1.000						1	1.000					
2	R: Buffer capacity	0.451	1.000					2	0.417	1.000					2	0.454	1.000				
		0.000							0.000							0.000					
3	R: Capacity to learn and adapt	0.663	0.169	1.000				3	0.511	0.003	1.000				3	0.482	0.059	1.000			
		0.000	0.032						0.000	0.990						0.000	0.619				
4	R: Capacity for self-organisation	0.634	0.288	0.417	1.000			4	0.560	0.225	0.189	1.000			4	0.438	0.156	0.149	1.000		
		0.000	0.000	0.000					0.000	0.045	0.093					0.000	0.178	0.200			
5	Q: Wellbeing	0.045	0.203	-0.132	0.115	1.000		5	0.293	0.446	-0.128	0.376	1.000		5	0.106	0.048	0.027	0.041	1.000	
		0.617	0.022	0.138	0.195				0.022	0.001	0.318	0.003				0.422	0.721	0.847	0.766		
6	Q: Resilience	0.043	0.132	-0.058	0.133	0.193	1.000	6	-0.095	0.125	-0.262	0.057	0.173	1.000	6	0.143	0.133	-0.018	0.133	0.243	1.000
		0.615	0.117	0.489	0.113	0.043			0.433	0.302	0.030	0.646	0.210			0.246	0.280	0.894	0.280	0.082	