Article

Derivation of Indicators to Measure Sri Lankan Rice Farmers' Sustainable Agriculture Potentials: Insights from Rural Livelihood Assessment Framework

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Abstract: This paper systematically identifies the constructs and indicators to measure Sri Lankan rice farmers' Sustainable Agriculture potential (SAP) in the regions of Mahaweli Block H in Anuradhapura district, a dominant rice cultivation district in the country. Insights from Rural Livelihood Assessment Framework helped identify the primary constructs of SAP: The constructs of farmers' SAP are derived as Human, Social, Financial, Physical, and Natural capitals. The principles of Sustainable Agriculture discussed in modern literature and the various research studies carried out in this domain are insightful to derive an exhaustive list of indicators that might adequately explain the constructs of SAP. The researcher adopted a quantitative descriptive approach, developed a comprehensive set of indicators (130), pre-tested them, and conducted a pilot survey with 64 samples. The measurement model analysis techniques in PLS-SEM helped shorten the Questionnaire with the most productive questions (87). This short-listed Questionnaire was again surveyed in a larger sample space, 386, to attest to their validity further. The study found five constructs and 87 productive questions that can explain farmers' SAP, and the researcher believes that these compositions of SAP and the indicators will be helpful for future researchers.

Keywords: capital assets; formative indicators; PLS-SEM; rural livelihood; Sri Lankan rice farmers; sustainable agriculture

Introduction

Sustainable aspects of agriculture are widely discussed topics in global forums today. United Nations General Assembly (2012) recognizes sustainability aspects of agriculture with more focus on ecological and social factors, including food security needs. Also, the United Nations Department of Economic and Social Affairs for Sustainable Development (2021) reemphasizes this unprecedented need for food and agriculture sustainability for the 21st century. The Sri Lankan government also realizes the timely need to implement measures to transition agriculture to a more sustainable aspect, focusing on rice cultivation. Even though the government tried to transition agriculture into more organic-centric, it failed. Banning chemical fertilizer is a massive social, economic, and political failure in the country. This failure shows that Sri Lankan farmers' potential for Sustainable Agriculture (SA) appears not appropriately known by policymakers.

Principles of Sustainable Agriculture

The principles of sustainable agriculture and its importance have become increasingly discussed in economic, political, and academic domains in many parts of the world over the last decades. Lichtfouse et al., 2009 suggest the SA addresses the world's food-securing needs for the ever-rising population while preserving resources for future generations. Conway & Barbier, 1990; Ackerman et

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al., 2014; Scherer et al., 2018) define sustainable agriculture as a dynamic and complex ecosystem that can fulfil the food needs within acceptable social, economic, and environmental costs and be resilient to environmental and economic changes. UN General Assembly (2012) recognized the diversity of agricultural systems and processes in the emergence of growing food demands for the world's rising population. United Nations passed a global resolution to promote SA production and productivity, mainly focusing on developing countries. These emphases were reasserted in (The rio+20) conference under the sustainable development goal to "End hunger to achieve food security and improved nutrition and promote SA Sustainable Development Goals 2(SDG2).

FAO (Zoveda et al.,2014) defines five fundamental principles of sustainable food and agriculture that balance the social, economic, and environmental dimensions of sustainability:

- Improving efficiency in the use of resources;
- Conserving, protecting, and enhancing natural ecosystems;
- safeguarding and improving rural livelihoods and social well-being;
- Strengthening the resilience of people, communities, and ecosystems; and
- Promoting good governance of both natural and human systems.

Present Characteristics of Rice Cultivation

The Sri Lankan economy contracted by 3.6% due to the Covid-19 pandemic. The agriculture sector also reported a 2.3% shrinkage as of the last quarter 2020. Nevertheless, the rice-growing and processing industry has shown promising resilience to the pandemic by gaining an expansion of 5.7%, favouring the economy (Department of Census and Statistics, 2021). Table 1 reflects the efforts of farmers who have provided almost the national rice demand over the last decade. The annual report issued for 2022 by the central bank of Sri Lanka reported a 6.9% contribution from agriculture to the national output in the year 2021 which shows the regaining of the agriculture sector in the country amidst the post-recovery of the pandemic. However, the present situation might differ due to the prevailing hard-hit economic crisis.

Table 1. Economic indicators of present rice cultivation.

Indicator	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Production index (Base Period: (2007 - 2010 = 100)	103	124	90	129	118	64	105	123	137	138
Contribution to national Consumption (%)	99.1	99.5	85.0	94.4	99.3	76.1	94.4	99.5	99.6	96
Import Expenses (CIF), Rs. Mn '000	3.1	2	37	18	2	46	17	2.3	2	15
Export Revenues Rs Mn '000	1	1	1	1	1	1	1	2	-	-
Per cent of GDP	1.4	1.6	1.2	0.9	0.6	0.5	0.7	0.7	0.8	0.7

(Source: Department of Census and Statistics, 2021; Economic and Social Statistics,2022).

However, farmers increasingly depend on chemical fertilizers (CF). Despite growing production volumes, organic fertilizer (OF) use is dramatically declining. Around 70% of the farmers are hardcore inorganic fertilizer users, whereas the rest are still in the mix of inorganic and organic users. The use of chemicals for other purposes has also increased during the last six years. The indicators shown in Table 2 below reflect the intense use of chemicals, which could be counter-effective to sustainable agriculture principles discussed later in this chapter.

Table 2. Farming applications in current rice farming.

Applications	20/21	19/ 20	18/ 19	17/18	16/17	15/16	14/15
Use of Chemical Fertilizers	67.2%	69.70%	66.80%	62.50%	57%	68%	64%
Use of Chemical and Organic Fertilizers	31.5%	30%	32.90%	35.80%	42%	31%	35%
Use of Organic Fertilizers	0.9%	0.10%	0.20%	0.50%	-	-	-
Applying Straw Directly to The Paddy Field	92%	86%	87%	90.9	89%	90%	86%
Use of Chemical Insecticides	63%	71%	74%	74%	58%	70%	72%
Use of Chemical Weedicides	83%	83%	84%	81%	78%	80%	84%

(Source: Department of Census and Statistics, (2021/2022)).

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Nevertheless, farmers have been producing almost the total rice demand in the country. They are not satisfied with the profitability and equitability of their income (Wijesooriya et al.,2020), and their profit margin is non-excessive compared to the bank interest rates (Senanayake & Premaratne, 2016). These findings raise questions on the productivity of CF and the effectiveness of subsidiaries provided on CF in modern rice cultivation. The intense use of chemical weedicides, pesticides, and fungicides are arguably evolved as alternative remedies to mitigate the side effects caused due to unregulated CF use. Excessive use of pesticides in Sri Lankan agriculture is a growing concern (Nagenthirarajah & Thiruchelvam, 2008; Watawala et al., 2010). Lack of knowledge and information on the detrimental effects of overusing pesticides and other chemicals is critical in the sector (Watawala et al., 2003; Nagenthirarajah & Thiruchelvam, 2008; Jayasinghe & Munaweera, 2017; Jayasinghe, 2017; Nishantha, 2015). It is widely claimed that chemical fertilizers' quality cannot always be guaranteed, with some products not even reaching the minimum standards due to their chemical and nutrient composition being potentially inconsistent or dangerous.

These findings evidence that the severity of chemical fertilizer usage and other intense uses of chemicals have been rampant across the local agricultural sector. Despite the efforts made by the government and non-governmental agencies to promote the more effective use of chemicals in agriculture, those measures did not yield anticipated results. Sri Lankan agricultural systems look economically and environmentally unsustainable and compromise food safety (Weerahewa, 2021). The situation does not favour sustainable agriculture (SA) principles and standards that many parts of the world are trying to adopt today. The researcher views as government's effort to transition agriculture into more organic-centric farming as the right way forward. However, the approach to doing so was a massive failure. Therefore, the researcher suggests that as the initial step, the government should have assessed the farmer's Sustainable Agriculture Potential (SAP) before the sudden ban on CF imports.

Government's Decisions to Transition Agriculture to A Sustainable Path

In addressing the need for more economical, social and environmentally friendly agriculture, the government stopped importing CF, marking a massive step toward transitioning Sri Lankan rice cultivation into a more sustainable path. The ban on chemical fertilizers in 2021 was inspired by the Sri Lankan government's focus on promoting and popularizing organic agriculture. This policy might have been developed based on claims of the adverse effects of chemical fertilizers mentioned above. The high import cost of agrochemicals, the unbearable subsidy schemes and the profitability concerns on CF use are some of the underpinning concerns for such a policy decision. Also, the connection drawn between the use of chemical fertilizers and an increased incidence of cancer and chronic kidney disease found among farmers within the dry zone might be a concern. Nevertheless, the direct relationship between chemical fertilizers and these illnesses is subject to further investigation (Lanka, 2022). However, regardless of its motives, the policy decision failed. The decision was overturned within less than a year.

The decision to ban CF use has erupted a massive perturbation in the rice cultivation sector. The farmers reacted to the situation by coming out to the streets in large processions showing their agitation against this decision. Their frustration and dissatisfaction show the magnitude of the issue, which created doubts about the continuation of cultivation and fulfilling the food security need of the country in upcoming seasons. Over six or so decades, the farmers have been encouraged to use CF through a chain of subsidiaries while delivering CF to their doorsteps (Central Bank, 2020b). During the introduction of CF, the practice of CF use had sometimes been ascribed to their individual preferences. (Department of Census and Statistics of Sri Lanka,1962). The practice has been continued by applying quantities determined at their whims in farm fields, perhaps not knowing the actual cost of it and other consequences. Irrespective of the outcomes, they are very attached to using CF in modern rice farming.

The country's foreign currency reserves had reached $8,864.98 million as of June 30, 2019. Before the Covid-19 break, on February 28, 2020, the resources were at $7,941.52 million. But as earnings from tourism dropped from $3,606.9 million in 2019 to $506.9 million in 2021 and foreign employment remittances dropped from $6,717.2 million to $5,491.5, the reserves started depleting. The reserves

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fell to $4,055.16 million in end-March 2021, $2,704.19 million at the end of September, and $1,588.37 million by end-November 2021. At the end-February 2022, data from the Central Bank of Sri Lanka's website showed the total official forex reserves at $2,311.25 million, which suffices for just over 1.3 months of imports. (Central bank, 2022). This dramatic drop in foreign reserves signals that farmers would no longer have ample amounts of chemical fertilizers in the market as they used to. The current national inflation has reached over 60% and keeps increasing (Central bank, 2022). Therefore, the farmers' affordability of the new market price of imported chemical fertilizers is questionable. Farmers must find a way forward for more economical, social, and environmentally friendly rice farming.

This failed decision of governments' efforts to transition agriculture into a more sustainable path shows that the policy makers and decision-makers are not fully aware of farmers' SAP. The researcher believes it is a timely need to assess farmers' SAP, which will bring the ground evidence on farmers' potential to adopt more SA-friendly farming. This evidence will be imperative to the future decision of the way forward. However, the researcher realizes that measuring farmers' SAP is not straightforward and attempts to propose a scientific model and set of indicators to measure farmers' SAP through a research study in Mahaweli Block H of Anuradhapura District of Sri Lanoka. The research requires defining the constructs of SAP and identifying a comprehensive set of indicators to measure those constructs.

There are various research studies (Petway et al., 2019; Waseem et al., 2020; Dharmawan et al.,2021; Gebska et al., 2020; Lichtfouse et al., 2009; Curry et al., 2012; Cusworth & Dodsworth, 2021) in this research discipline and researchers have found out several factors which could measure the farmers SA potential. The researcher finds these studies are very insightful for his objectives. However, no consolidated framework with explicit constructs and indicators can be directly adopted to assess farmers' SAP. The researcher proposes a measurement framework and indicators developed following the scientific process in this paper.

Research Question

What constructs can define farmers' sustainable agriculture potential (SAP), and what are the measurement indicators to measure those constructs?

1. What are the determining constructs of farmers' sustainable agriculture potential?
2. What are the proxy indicators that might comprehensively explain those constructs?
3. How to differentiate the most productive indicators derived in the above step
4. How to conclude the validity of those indicators

Research Objective

This study's research objective is to identify the constructs of farmers' sustainable agriculture potential (SAP) and determine measurement indicators to measure those constructs.

1. To identify the constructs of farmers' sustainable agriculture potential (SAP)
2. To find out a comprehensive list of proxy indicators, those will explain those constructs
3. To differentiate the most productive indicators derived in the above step
4. To conclude the validity of those indicators.

Composition of Farmers'SAP

In general, most farmers are a subset of rural livelihood. According to DFID, "A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for 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. Ashley & Carney (1999) adapted this definition from Chambers & Conway (1992), who introduced sustainable rural livelihood assets in DIFID's sustainable livelihood framework. The framework describes the rural livelihood assets in five main categories: Human Capital, Social Capital, Financial Capital, Physical Capital, and Natural Capital. Carney (1998), Scoones (1998), and Batterbury & Forsyth (1999) supplemented this explanation of five-dimensional capital assets. The researcher adopts these five capital assets to help identify the

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farmers' SA potential. The following section of this chapter explains each capital asset's literature synthesis.

Table 3. The constructs of Farmers' SA potential.

Constructs of farmer's SA potential	*Type*	*Category*
Farmers' SA Potentials (FSAP)	Composite	Latent
Human Capital (HC)	Independent	Latent
Social Capital (SC)	Independent	Latent
Financial Capital (FC)	Independent	Latent
Physical Capital (PC)	Independent	Latent
Natural Capital (NC)	Independent	Latent

This study aims to formulate a measurement model using existing literature suggestions and find a way of measuring the mechanism of farmers' SAP. Since farmers are a prominent subset of rural livelihood, the researcher adopts the rural livelihood assessment framework for the assessment model with five capital assets shown above. However, the explaining indicators of those five capital assets required the representation of sustainable agriculture principles and standards. The researcher believes this model is suitable for this expletory study as defined by its objectives. The following section of this paper discusses the finding of the indicators to measure those indicators.

Research Method and Materials

The proposed measurement model shown in Figure 1 consists of five latent variables. The study aims to explore the ground reality of farmers' SAP. Quantitative research approaches using a structured questionnaire are common research studies researchers adopt in investigating socio-economic and natural phenomena like this study (Leedy & Ormrod, 2001; Cohen et al., 2007). Blanche et al. (2006) suggest a quantitative-descriptive approach to investigate the epistemologies related to constructs of this nature. The researcher adopts a quantitative descriptive approach for this study. According to quantitative measurement theories explained in the literature (Hair et al., 2017), researchers can derive measurement indicators in two ways, either in a "formative" or "reflective" manner, which depends on the nature of the construct of the study.

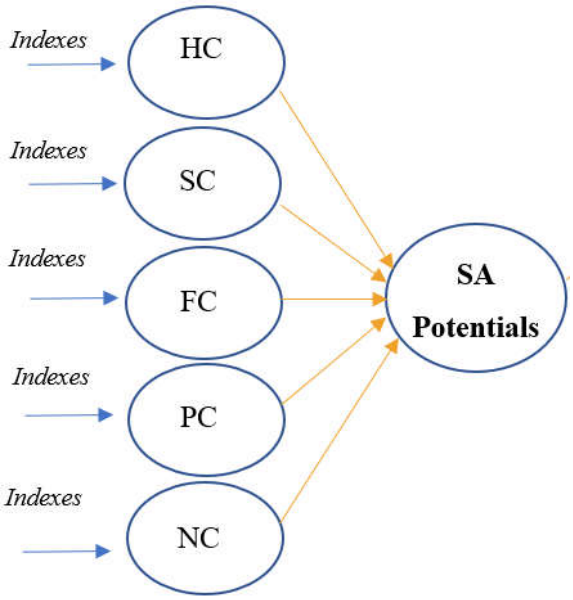

Figure 1. Measurement model for farmers' SA potential.

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Formative and reflective indicators

Diamantopoulos & Winklhofer (2001) suggest forming formative indicators if the causal priority between indicators and construct is from indicators to the construct. On the contrary, if the causal focus is from construct to indicator to form reflective indicators. Also, Fornell (1982) suggests formulating formative indicators if a combination of indicators explains the construct or developing reflective indicators if a trait presents the indicators. Similarly, Rossiter (2002) argues for selecting reflective indicators if indicators represent consequences and formative ones if indicators represent the cause. The following diagram (Figure 2) demonstrates these two measurements' coverage differences between the abovementioned research domains. The formative approach maximizes the variances explained for the construct. Maximizing the variance explained is a fundamental requirement in this study. i.e., to exhaustively identify underlining variables of each latent construct that would optimally contribute to the formation of constructs. Those required distinguish indicators to explain each capital asset which does not necessarily correlate with each other but should contribute to explaining (formation) the construct giving substantial comprehension.

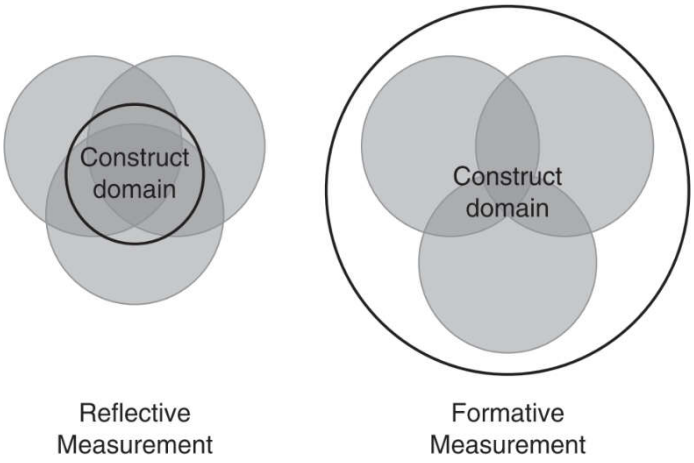

Figure 2. Formative vs Reflective Indicators.
(Source: Hair et al., 2017)

As necessitated by the objectives and the context of this study and combined with the literature suggestions above, farmers' SAP are treated as combined causal effects of the five capital assets.

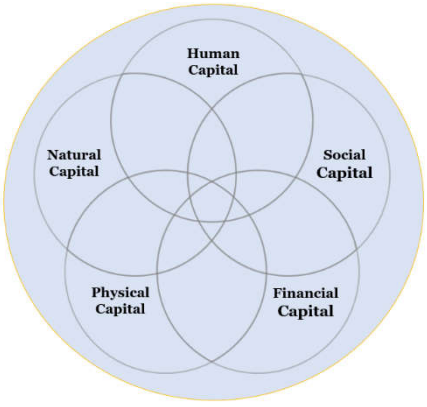

Figure 3. Composition of Farmers' Sustainable Agriculture Potential Measurements.
(Source: Author's creation)

Data Analysis Techniques

The literature suggests Partial least squares structural equation modelling (PLS-SEM) technology to assess models with such formative indicators (Hair et al., 2017). PLS-SEM techniques

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provide parameters, algorithms, and rules for such analysis, which are discussed in detail in this chapter below. PLS-SEM techniques require some alternative reflective questions on each formative latent construct (in this case, five capital assets) to prove the convergent validity of the constructs, as explained in measurement theory (Hair et al., 2017). Considering these requirements, the following Table shows this study's formative and reflective indicator requirements.

Table 4. Formative and reflective constructs of the model.

Variable	Type	criteria
Human Capital (HC)	Formative	• The constructs are composed of a combination of indicators
Social Capital (SC)	Formative	
Financial Capital (FC)	Formative	• No covariance is expected among indicators
Physical Capital (PC)	Formative	• The indicators are not mutually exchangeable
Natural Capital (NC)	Formative	• The indicators cause the constructs
HC, SC, FC, PC, NC	Reflective	• The indicators reflect the consequences of the construct • Covariance is expected among indicators

Formation of indicators

Scales and Measurement

Determining the scale of measurement is essential in deriving the questions. Hair et al. (2016) suggest using ordinal scales, such as Likert scale coding, as standard in deriving similar measures ensuring the equidistance of scale points. The researcher paid particular attention to the coding to fulfil the requirement of equidistance in using such scales. Therefore the questions are framed in the scale of 5-point Likert scale with the categories (1) strongly disagree, (2) disagree, (3) neither agree nor disagree, (4) agree, and (5) strongly agree, with the inference that the "distance" between categories 1 and 2 is the same as between categories 3 and 4. The questions are planned for pre-testing through scholarly reviews and assessed through a pilot survey to test the scale's validity and the questions' productivity.

Derivation of Measuring Indicators

A thorough literature review based on the above rural livelihood asset definitions reveals various socio-economic, socio-ecological, and sociocultural factors of farmers' SA potentials investigated in the previous studies. Table 5 below summarizes the outcome of the literature review indicators, and measurement scales the researchers have found in their studies domain over the past decades.

Table 5. Indicators and scales of farmers' sustainable agriculture potential.

Capital Assets	Indicators	Scales of measurements
Farmers' Sustainable Agriculture Potentials		
Human Capital Memon (1989); Petway et al. (2019); Porritt, Jonathon (2011); Radcliffe (2017)	Literacy level, Experiences Capitals, Household health, Living standards	Level of education, knowledge of SA., Number of years in farming, other non-farm skills being practised, the ability to use household labour, the presence of good household health, level of motivation, norms, and beliefs on SA.
Social Capital Rust et al. (2021); Putnam (1993), Bourdieu (1986) Melles & Perera (2020)	Trust, Norms, connectedness, Power, Reciprocity, Network structure	Increase in other assets due to membership or participation in Social networks, Labour support from group members; income gained through membership in groups, use of group tools, equipment, and infrastructure; trust in communities and farmer organization, Strength of

		Communication channels; food, labor, and other resource sharing practice
Financial Capital Mulimbi et al.(2019); Kiptot & Franzel (2014); Bowers (1995)	Direct and indirect financial benefits, Savings, and Debts	Crop yields as a proxy – e.g., kilogram per hectare produced in last season, last drought or flood affected frequencies, Income/yields, Savings, Labour income, Expenditure /Dependency ratio; off-farm income,
Physical Capital Myeni et al.(2019); Arellanes, et al. (2003);Petway et al. (2019)	Machinery, Buildings, Equipment, Cultivation well, Granary, Tools and equipment, Transport networks	Ownership and access to resources, Assessing levels and changes in conditions of and access to livelihood capitals, Asset ownership
Natural Capital Scherer et al. (2018); Bisht (2013); Serebrennikov (2020); D'souza (1993); Bowman & Zilberman (2013), Bowers (1995)	Soil, Water, Energy, Biological resources	Soil fertility (nutrients), soil organic carbon, agroforestry, and tree carbon, soil moisture content, biomass, runoff/erosion, pests, diseases observations and measurements, nature of neighboring land, water availability recyclability of resources and waste minimization, the impact of weather events and climate change

Human Capital

According to Coleman (1988), human Capital is new skills and capabilities that enable one to act in a new way to prove productivity. Acquiring knowledge, building awareness and skills, developing positive attitudes, and blending values and beliefs with modern farming practices could be the most significant motivating factors to adapt the SA practices. Improved literacy level, experiences, skills, household health, and living standards would be a strong determinant of Human Capital, which researchers have investigated in similar studies (Memon, 1989; Petway et al., 2019; Porritt Jonathon, 2011; Radcliffe, 2017)

Social Capital

Social Capital is an asset produced when people interact, creating relationships and networks of trust and shared understanding (Gotschi et al. 2008). According to Sobel (2002), social Capital describes circumstances in which individuals can use membership in groups and networks to secure benefits (Putnam et al. 1993), and Coleman (1994) in detail defines Social Capital as the networks, norms, trust, and links of reciprocity that facilitate cooperation and coordination. Accrued Social Capital of farmers was instrumental in uptaking new agricultural practices; a study of young Greek farmers found that those with higher social Capital were more likely to be innovative (Koutsou et al., 2014).

Financial Capital

Cash flow generation is essential for farmers to afford to take risks and develop a longer-term vision than daily subsistence. A synthesis carried out by Vorley (2002) on projects of 'policies that work for sustainable agriculture and regenerating rural livelihood' demonstrates that the self-financing capacity of Brazilian farmers is vital to allow them to adopt more environmentally friendly practices. In the same study, limited access to credit is a significant impediment to small-scale agricultural production. Credit programs seldom reach smaller farmers due to power disparities and rent-seeking by larger farmers. The Bolivian case study under the same project explains that in contrast to large-scale mechanized agriculture, smallholders had no or little access to credit since they had no collateral resulting in little commercial value for banks. The case studies also demonstrate the importance of off-farm income, such as retirement funds and city jobs. Many low-income households use migrant relatives' remittances for Consumption or to pay expenditures such as education and

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health, so little usually remains for investment and farm-based accumulations (Tacoli, 1998). In general terms, financial Capital explains an individual's or institution's savings, credit, and remittances, in this case, which would be direct determinants of farmers' ability to adapt SA practices.

Physical Capital

Many researchers have investigated the ownership of farm plots, machinery, buildings, equipment, cultivation-well, granary, tools and equipment, transport networks, and access to technologies, including ICT, in assessing farmers' physical Capital, which might influence their readiness for SA adaptation (Myeni et al.,2019; Arellanes et al., 2003; Petway et al., 2019). The farm size and ownership of the farming plot are significant factors in SA studies. Gachango et al. (2015) ; Rodríguez-Entrena & Arriaza (2013) find that the size of the farm positively relates to conservation agriculture adaptation. Whereas (Läpple & van Rensburg, 2011; Kallas et al., 2010) find that farm size inversely relates to the adaptation capabilities of organic farming. However, in their literature synthesis, Knowler & Bradshaw (2007) found that several researchers have tested this variable in 18 SA studies. Six studies had seen a positive correlation with SA, two were inversely related to SA, and ten studies were found insignificant. Given the mixed findings of previous researchers, the researcher believes farm size could contribute to farmers' readiness for SA relating in either way. Also, the convenience of renting and continuing with farmland is investigated in similar other studies.

Natural Capital

Rezvanfar et al. (2009) concluded that accelerated soil erosion and declining fertility are significant constraints to agricultural production and SA. Soil fertility is the ability of soil to sustain plant growth and optimize crop yield. The organic and or inorganic fertile fill the deficiencies. According to (Spaling & Vander 2019), Farmers claim that retaining crop residue or regularly adding mulch to the field improves soil fertility (organic matter, nutrients). Zahra (2018) finds that soil fertility declines because of the growing use of chemical fertilizers and pesticides. The SA often reports increasing soil organic matter and concerns about nutrient availability. Some researchers are pointing out that soil organic matter is contingent on the availability of organic inputs (crop residue, manure, compost) (Hobbs et al., 2008; Twomlow et al., 2009; Luo et al., 2010; Marongwe et al., 2011; Mupangwa et al., 2012; Palm et al., 2014; Dordas, 2015). The proximity of organic inputs also affects availability. Fields nearer to the homestead usually have higher organic matter because sources of manure and compost are nearby (Zingore et al., 2007; Guto et al., 2012).

Research Questionnaire

The exhaustive literature review summarized above produced 108 formative questions and 22 reflective questions in the form of statements. The frame of the questions is so that the respondent can provide their answer on a scale of "Strongly Disagree" to "Strongly Agree." (5 points Likert scale). The complete research questionnaire is attached in Annex-1 of this paper.

Table 6. The number of Formative and reflective indicators of constructs.

Capital Asset	*Number of formative indicators*	*Number of Reflective indicators*
Human Capital	38	5
Social Capital	22	4
Financial Capital	15	3
Physical Capital	15	5
Natural Capital	18	5

Pre-testing of the Questions

Pre-testing a questionnaire using a small number of respondents is a widely used research practice to extract the most productive and appropriate questions (Mugenda & Mugenda, 2003). There is broad consensus on this practice in the literature on the importance of pilot studies on data collection instruments. This step is vital to ensure that respondents have clarity and understanding of the questions with no ambiguity (Reynolds & Diamantopoulos, 199; Babbie, 2004; Moser & Kalton, 2004; Neuman, 2006: McBurney & White, 2007). Also, such initial testing enables the researcher to

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test the length and sequencing of questions (Easterby-Smith et al. 2021) and to discover errors (Reynolds & Diamantopoulos 1993). Such testing helps train the research team (Cooper & Schindler, 2003), rectify inadequacies, and reduce biases. A pilot survey also serves to determine how appropriate and comprehensive the questions are and reveal vague questions (Sekaran, 2003); protect against redundancy of questions (Babbie, 2004); assess marginal questions (Moser & Kalton 2004), and refine and perfect the instruments (Synodinos, 2003).

Sampling Population

Anuradhapura district is the dominant rice-producing district in Sri Lanka. According to figures published in the census and statistics in 2019/2020, during the "Maha" cultivation season (the primary rice cultivation season in Sri Lanka), Block H of Mahaweli accounts for 20% of the land area in the Anuradhapura district. This division H comprises approximately 14,170 hectares of developed land under four colonization schemes. Figures 4 and the Table below show the geographical layout of block H and sown extents of rice and their percentages in the regions belonging to it. Most rice cultivation plots (more than 80%) are less than 2.5 Acre plots which denotes that the sown extent is a fair representation of the farmer population in this region.

Table 8. Sown Extent (acres) in Mahaweli zones H in Anuradhapura district.

Rice cultivation region in block H	*Acres*	*% To District Total*
Galnewa	9082	3%
Meegalewa	5220	2%
Galkiriyagama	5367	2%
Madatugama	7307	2%
Eppawela	8122	3%
Tabuttegama	7129	2%
Nochchiyagama	8257	3%
Thalawa	7437	3%

Source: Department of Census and Statistics Sri Lanka. (2020).

Sample size

According to Han et al. (2018), 225 farmer organizations and 25,623 registered members are in block H of Mahaweli. Aheeyar (2007) found that 94% of the farmers in block H engage in rice cultivation. Krejcie & Morgan (1970) developed a table to determine a population's sample size for easy reference. This reference table shows that 377 samples would be sufficient for a size of 20,000 people and 379 for a population of 30,000. Therefore, the researcher adopts 380 samples for this study. The Table below shows sample slices determined for each region.

Table 9. The number of samples by each region.

Cultivation divisions in Block H	*Sown Extent*	*Number of samples*
Galnewa	9082	60
Meegalewa	5220	34
Galkiriyagama	5367	35
Madatugama	7307	48
Eppawela	8122	53
Tabuttegama	7129	47
Nochchiyagama	8257	54
Thalawa	7437	49
Total Mahawali (H) Block	57921	380

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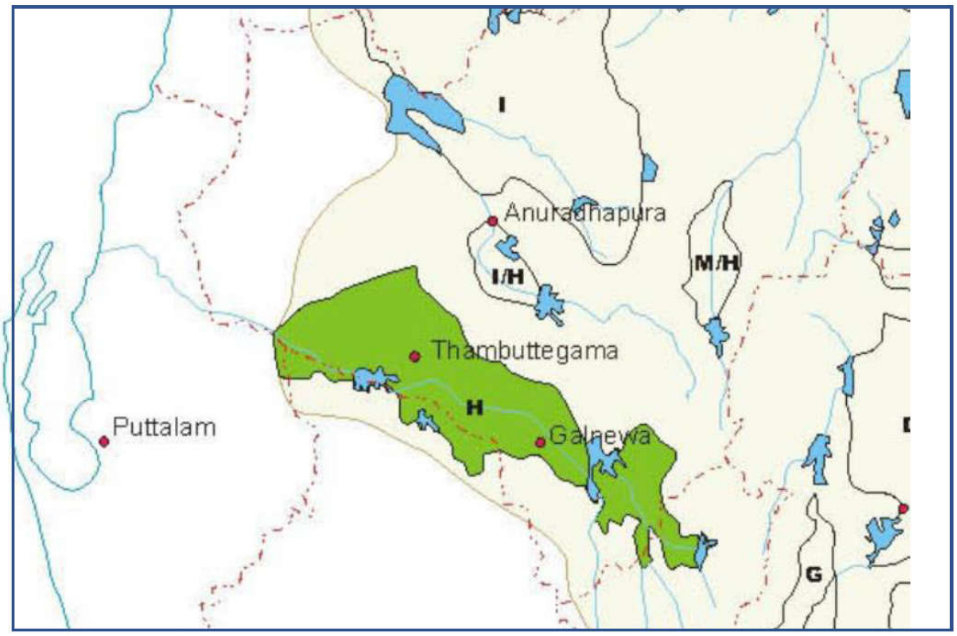

Figure 4. Geography of Mahaweli system H Block.
(Source: Aheeyar, (2007)

Pilot survey

Some convenient samples were collected through face-to-face interviews with 64 respondents from May 23 to June 4 2022, in some regions shown above. Key informants (Government Agricultural field officers of these divisions) administered the Questionnaire. Respondents for the Questionnaire were identified by referring to the government's fertilizer distribution lists available to agriculture officers of this division.

Data Analysis of Pilot Survey

The guidance and suggestions explained in the PLS-SEM literature (Hair et al.,2017) are closely followed in each data analysis stage and in concluding the results. As discussed above, the constructs consist mainly of formative and several alternative reflective indicators for convergent validity testing. The measurements for five capital asset constructs comprised 102 formative indicators and 22 reflective indicators. The reflective indicators support measuring the convergent validity of each construct. The measuring indicators are on ordinal Likert measurement coded following the abovementioned techniques. The measurement analysis necessitated applying the following rules and conditions suggested in the literature, and the analysis differentiated the most effective and reliable indicators for the initial Questionnaire.

Principle Component Analysis

Principle component analysis is vital in finding out the most compelling questions for research instruments, usually performed through pilot surveys. PLS regression differs from regular regression, however, because in developing the regression model, it constructs composite factors from the multiple independent variables and the dependent variable(s) through principal component analysis. PLS regression is an analysis technique that explores the linear relationships between multiple independent variables and a single or multiple dependent variable(s). In developing the regression model, it constructs composites from the multiple independent and dependent variables (s) through principal component analysis (Hair et al., 2017). The measurement model analysis described below is equivalent to the principal component analysis and fulfils this essential need for the new instrument development of this research.

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Measurement indicator Analysis (PCA)

The literature suggests applying the following steps in sequence in assessing formative indicators like these constructs, facilitating the analysis of the indicators with 64 samples collected during this survey.

Step 1: Assess the convergent validity of formative measurement constructs
Step 2: Assess the formative measurement constructs for collinearity issues
Step 3: Assess the Significance and relevance of the formative indicators
(Hair et al. (2017)

Assessing Convergent Validity:

The following method suggested in the literature for convergent validity (CV) testing is considered in measuring and evaluating formative measurement indicators. The technique analyses the CV of formative constructs by calculating the correlation of formative measurement with alternative reflective measures of the same construct (i.e., each construct is considered as separate sub-models as "construct-formative" and construct-reflective" as shown in Figure 3. The formative indicators, in a linear way, form the formative latent construct, and the explained variance (R2 value) of the compositely created latent construct should be equal to 1 in an ideal situation (Bollen, 2011; Bollen & Bauldry, 2011)

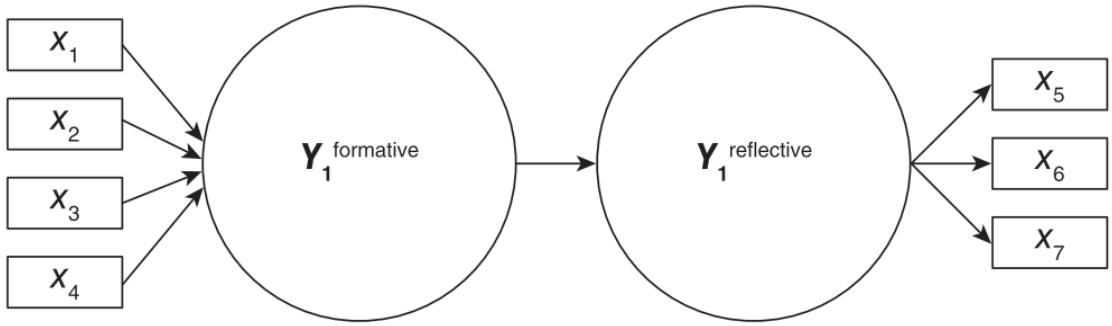

Figure 5. Model to measure convergent validity of formative indicators.
Source: (Hair et al. (2017)

The literature suggests the strength of the path coefficient linking the two constructs (formative and reflective) is of magnitude 0.80 or a minimum of .070 for satisfactory convergent validity. In other means, this reflects the indicative R^2 value of the construct to be 0.64 or at least 0.50 to prove the convergent validity. The five formative latent constructs of the model were analyzed by applying the above criteria and rules. Table 6 below depicts the summary of the CV analysis of formative constructs of the model

Table 10. Results of convergent validity analysis.

Latent construct	Path coefficient	R^2 Value
$HC^F \rightarrow HC^R$	0.924	0.853
$SC^F \rightarrow SC^R$	0.784	0.615
$FC^F \rightarrow FC^R$	0.895	0.801
$PC^F \rightarrow PC^R$	0.828	0.686
$NC^F \rightarrow NC^R$	0.700	0.491

Assessing Collinearity of indicators:

In PLS-SEM literature, collinearities of formative indicators are measured using the variance inflation factor (VIF), defined as the reciprocal of tolerance. The tolerance represents the variance of one formative indicator, which the other indicators in the same construct do not explain. In this concept of PLS-SEM, a tolerance value of 0.20 or lower and a VIF value of 5 or higher indicate a potential collinearity problem (Hair et al., 2011). All formative indicators' collinearity analysis (VIF values) shows that some indicators have exceeded the above thresholds. These questions were ruled

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out from the Questionnaire and not considered as productive to retain as measurement. Annex 02 of this paper includes the VIF analyses of the above five formative constructs.

Assessing significance and relevance

The relevance of the indicators' contribution in forming the construct is examined by analyzing each indicator's outer weight (relative importance) and outer loading (absolute importance). The significance of such contribution is measured using the bootstrapping technique provisioned in PLS-SEM techniques. The following rules are proposed in the literature to determine their relevance and significance.

1. When an indicator's weight is significant, there is empirical support to retain the indicator
2. When an indicator's weight is not significant, but the corresponding item loading is relatively high (i.e., ≥0.50) or statistically significant, the indicator should generally be retained.
3. If the outer weight is non-significant and the outer loading is relatively low (i.e., <0.5), you should strongly consider removing the formative indicator from the model.

After applying these rules to this measurement model, the results show some indicators did not satisfactorily comply with the above rules and conditions. They were ruled out from the Questionnaire and not considered effective measurements. The results of significance and relevance analyses of formative indicators are included in Annex -2 below. The indicators marked in "green" in the results tables are the indicators that passed the tests. The figures marked in "light green" the figures within the acceptable threshold.

Results of the Pilot Survey

After applying the above data analysis rules, less relevant and insignificant measuring variables were eliminated from the measurement model. Out of 108 formative questions of five constructs, only 69 indicators were qualified to be retained. Of 22 reflective indicators, 18 were found as productive measurements. The indicators carried forward for a compressive survey with a larger sample size to further validate their applicability.

Table 11. Productive Indicators to measure farmers' sustainable agriculture potentials.

#	Indicator	Measuring Indicators description
		Human Capital
	Human Capital - Generic reflective indicators	
1.	HCGQ1	I am well motivated to continue with rice farming
2.	HCGQ3	I am well aware of nature-friendly farming activities
3.	HCGQ4	I regularly apply nature-friendly farming activities in rice farming
	Human Capital -Composite formative indicators	
		Health and well-being
4.	HCHAW3	It is infrequent our health issues impact our rice farming activities
5.	HCHAW5	I am well satisfied with my relationships with friends
6.	HCHAW7	I am not worried at all about everything that is happening these days
7.	HCHAW8	I am optimistic about the next 12 months
		Knowledge and Farming Experiences
8.	HCKAFE10	I know the most effective method that can control weeds
9.	HCKAFE5	I know the importance of utilizing organic compost
10.	HCKAFE6	I know the irrecoverable consequences of neglecting irrigation on time
11.	HCKAFE8	I know biological methods to control pests effectively
		Planning and organizing
12.	HCPAO3	I do the farming at the proper time
		Attitudes
13.	HCA1	We must protect natural resources for the next generation even if it incurs short-term losses to our outturn

14.	HCA3	Intense use of chemicals in farming affects the health of people and animals
		Beliefs and values
	HCBAV1	I believe that minimizing the use of chemicals is a timely need
	HCBAV3	The yield produced through fewer chemicals is healthier
	HCBAV6	My children/child will continue with our farming traditions
		Social Capital
	(SA practices Examples: Selecting better seeds for improved yield, minimizing chemical fertilizer use, improving soil fertility, minimum use of chemicals in pests and weed control, minimizing water waste and pollution, etc.)	
Social Capital - Generic reflective indicators		
15.	SCGRQ1	I am living in a society where I am thoroughly encouraged to adopt SA practices
16.	SCGRQ2	I am living in a society where I am fully supported in adopting SA practices
17.	SCGRQ3	I am living in a society where SA is considered an important
18.	SCGRQ4	I will gain more social recognition if I adopt SA practices
Social Capital -Composite formative indicators		
		Networks and connectedness, a) Bonding -similar individuals within a network, b) Bridging conservationists, c) Linkage -policymakers
19.	SCNBBL1	Farmer organization provides me with significant help for my farming activities
20.	SCNBBL2	I receive significant support from community associations in which I am a member of
21.	SCNBBL6	I receive significant support from agriculture researchers for my farming activities
		Trust and reciprocity
22.	SCTAR1	I trust the advice and support received from my fellow farmers on the above practices
23.	SCTAR4	I trust the advice and support received from banks and other financial institutions on the above practices
24.	SCTAR5	I trust the advice and support received from insurance companies on the above practices
25.	SCTAR6	I trust the advice and support received from agrochemical sellers on the above activities
		Norms and values
	SCNAV1	Some fellow farmers compel me to more nature-friendly farming practices
	SCNAV2	I am always happy to produce harvest with higher standards
	SCNAV3	I will receive more social recognition if I adapt to more environmentally friendly farming methods
	SCNAV4	I will receive better price/demand if I produce paddy using organic matter and with less chemical use
		Power
	SCP1	It is a condition of my land load to adapt the above practices
	SCP2	Paddy buyers give better rates to farmers who adopt those practices
	SCP3	Agro-Input sellers give discounts and credit facilities to farmers who adopt the above practices
	SCP4	I feel government officials are becoming more supportive of the farmers who adopt the above practices

	SCP5	I find that wealthy farmers in our society support us in adapting the above practices
		Financial Capital
Financial Capital - Generic reflective indicators		
26.	FCGRQ1	I am economically strong to continue with rice farming
27.	FCGRQ2	Getting financial aid for my farming needs is not challenging
28.	FCGRQ3	My rice farming is generally profitable
Financial Capital - Composite formative indicators		
		Savings and cash flow
29.	FCSACF1	Ensuring household food security is not a challenge for me
30.	FCSACF2	Meeting of financial needs of my family is not a challenge for me
31.	FCSACF3	I do make a good surplus in each season
32.	FCSACF4	Re-investing in rice farming is not a challenge for me
		Financial Credits
	FCFC3	I can borrow money from local providers easily for a reasonable interest rate
33.	FCFC1	Obtaining a loan from a state bank is not a challenge for me
34.	FCFC2	Obtaining a loan from a private bank is not a challenge for me
		Remittances
35.	FCR1	I receive substantial income from my other businesses
36.	FCR3	Though rice farming is my main job, I do part-time jobs with good earning
37.	FCR4	In addition to rice farming, I do other agriculture, which gives me a considerable income
38.	FCR5	I receive regular income from my savings in the bank
		Profitability
	FCP1	I get a fair price for my harvest, and the income is generally profitable
	FCP2	The selling price keeps increasing in parallel with the cost increase of agro-inputs
	FCP3	The profit I generate keeps increasing with the price increase of other household commodities
		Physical Capital
Physical Capital - Generic reflective indicators		
39.	PCGRQ1	I have the required types of machinery and equipment for rice farming
40.	PCGRQ2	I can afford to hire the types of machinery when needed
41.	PCGRQ3	I have access to SA agricultural knowledge
42.	PCGRQ4	I get market information easily
43.	PCGRQ5	I have easy access to agro-inputs selling outlets
Physical Capital - Composite formative indicators		
		Availability of machinery
	(Machinery examples (Sprayer machine, water pump, two-wheeler tractor, four-wheeler tractor, planter, harvester, etc.)	
44.	PCAOM1	I do possess the required agricultural types of machinery and equipment necessary for my farming
45.	PCAOM2	Maintaining those types of machinery is not an issue for me
46.	PCAOM3	I can afford to hire the above types of machinery whenever needed with no issues
47.	PCAOM4	The charges I pay for the hiring of types of machinery are affordable
48.	PCAOM5	The charges I pay for hiring types of machinery are reasonable

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		Access to information and consultancy services and market information
49.	PCAIS1	I listen to radio programs related to rice farming, and they are useful
50.	PCAIS2	I watch television programs on rice farming, and they are useful
51.	PCAIS6	I read newspaper articles related to rice farming, and they are useful
52.	PCAIS7	I regularly read the leaflet and broachers distributed on rice farming, and they are useful
53.	PCAIS3	I find helpful agriculture-related videos on the internet and social media, and they are useful
		Access infrastructure and availability of labour
	PCAIAL1	It is easy to access the paddy buyers
	PCAIAL2	It is easy to access agriculture suppliers and vendors
	PCAIAL3	It is easy to find the labour required for rice farming activities
	Natural Capital	
Natural Capital - Generic reflective indicators		
54.	NCGRQ1	The soil condition of my farm plot can be improved for organic fertilizer use
55.	NCGRQ2	I get an adequate water supply for my farming
56.	NCGRQ3	The location of my farm plot is less vulnerable to natural disasters
Natural Capital - Composite formative indicators		
		The soil fertility of the land
57.	NCSFL1	I think the soil fertility of my farm plot is in good condition
58.	NCSFL2	I think I can improve the soil in my farm plot for organic fertilizer use
		Availability of carbonic substances to improve soil fertility
59.	NCACS3	I can prepare the compost required for my farm plot
60.	NCACS4	I can find a good amount of green manure crop in the vicinity of my farm plot
61.	NCACS2	I can find reasonable amounts of poultry manure or cow dung in the vicinity of my farm plot
		Effectiveness of waterworks and adequacy of water
62.	NCEWAW1	The waterworks to my farm plot are well maintained
63.	NCEWAW2	I am satisfied with the timing of the water-releasing intervals for farming
64.	NCEWAW3	I can rely on rainwater, too, to a reasonable extent
65.	NCEWAW4	I can pump water to my plot if required
		Frequencies of whether extremes and animal attacks
	NCFWA1	I am not facing severe crop damage due to drought
	NCFWA2	I am not facing severe crop damage due to floods
	NCFWA3	I am not facing severe crop damage due to animal attacks

Validating the Questionnaire using a Larger Number of Samples

Data collection

Three key informants who were adequately oriented on the survey's objectives were deployed to conduct the study. These key informants administered the data collection in the prescribed locations during October and November 2022. The survey teams randomly met rice farmers at their doorsteps or farm fields and marked the responses for each question of the survey questionnaire in real-time. The data collection concluded after they collected 400 samples from each region. Stratified random sampling was the sampling technique adopted in this study.

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Data analysis

This data analysis aims to investigate further the validity of the selected question identified in the pilot survey. As detailed below, the techniques and guidance suggested in the PLS-SEM data analysis technique on measurement model analysis were deployed on each construct.

Human Capital

Human Capital is defined in five grouped well-being variables, Attitudes, Health & well-being, knowledge & experience, Planning & organizing, and Beliefs & values. These five grouped variables were measured using survey questions. The following diagram and Table show that the indicators comply with PLS-SEM's rules. This means those indicators are acceptable measures for the farmer's Human Capital contribution to SAP.

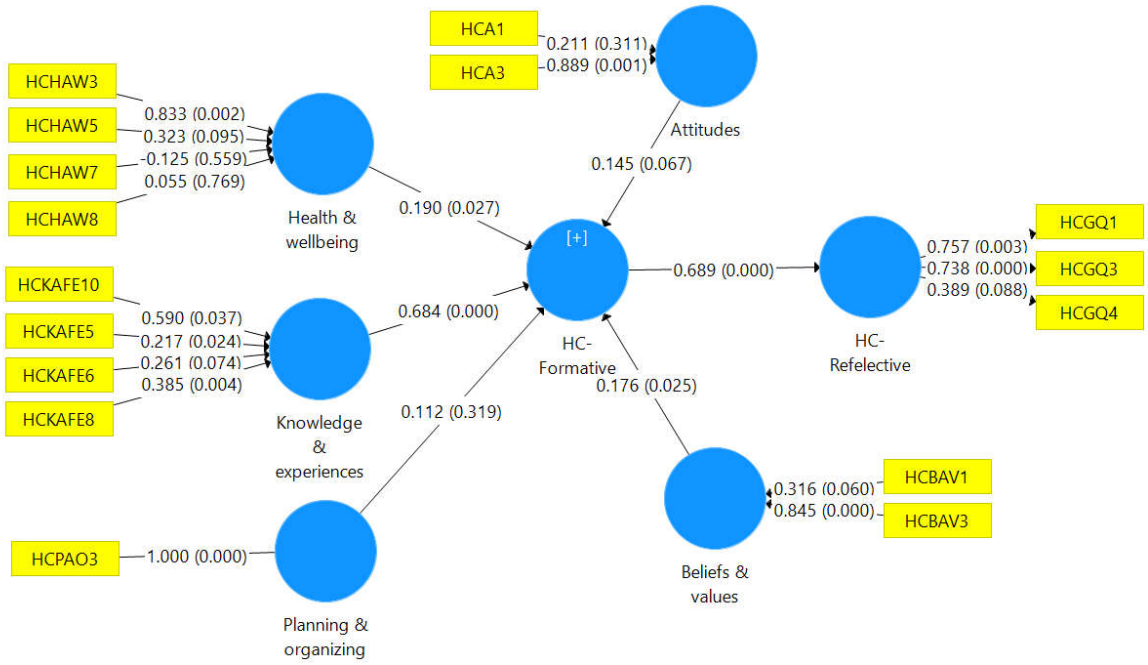

Figure 6. Path coefficient, significance, and relevance of Human Capital variables.

Table 12. VIFs of Human Capital Variables.

Inner Variables	*VIF*	**Outer Variables Continued.**	*VIF*
Attitudes		1.468HCHAW8	1.245
Beliefs & values		1.402HCHAW7	1.167
Health & wellbeing		1.281HCHAW5	1.178
Knowledge & Experiences		1.733HCHAW3	1.205
Planning & organizing		1.629HCBAV3	1.138
Outer Variables	***VIF***	HCBAV1	1.138
HCPAO3		1HCA3	1.244
HCKAFE8		1.478HCA1	1.244
HCKAFE6		1.509HCKAFE10	1.106
HCKAFE5		1.121	

The calculations resulted in a path coefficient value of 0.7 between formative and reflective constructs, approximately 0.5 R2, which is within the acceptable literature suggestions. The VIF values are also within the acceptable range, and each indicator's outer weights show the significance for acceptance.

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Social Capital

Social Capital is defined in five sub-dimensions: Power & Influences, Linkages & bonding, Trust & reciprocity, and Norms & values. The following figure and Table show that the indicators and the grouped variables satisfactorily complied with the PLS-SEM rules and requirements.

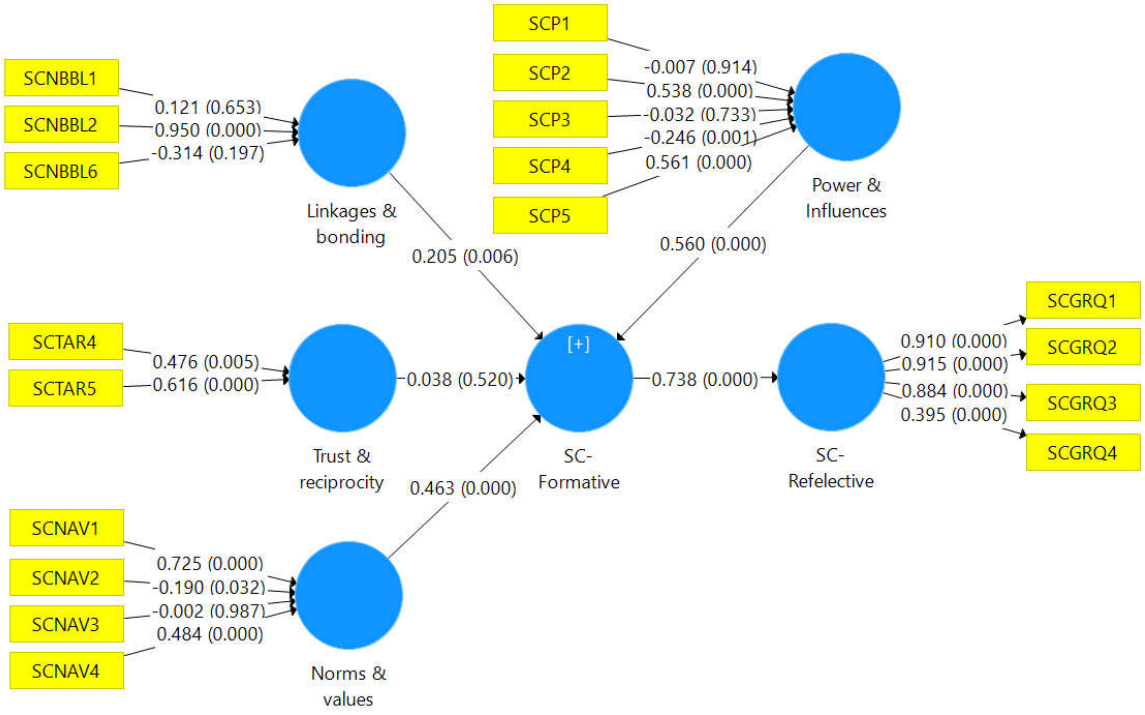

Figure 7. Path coefficient, significance, and relevance of Social Capital variables.

Table 13. VIFs of Social Capital Variables.

Inner Variables	*VIF*	*Outer Variables continued*	*VIF*
Linkages & bonding		1.077SCP1	1.239
Norms & values		1.662SCP2	2.816
Power & Influences		1.858SCP3	2.591
Trust & Reciprocity		1.269SCP4	1.016
Outer variables	***VIF***	SCP5	2.088
SCNAV1		1.203SCTAR4	2.351
SCNAV2		**1.265**SCTAR5	1.998
SCNAV3		**1.419SCNBBL2**	**1.372**
SCNAV4		**1.211SCNBBL6**	**1.051**
SCNBBL1		**1.362**	

Financial Capital

Like the other capital asset variables, Financial Capital is also defined using a set of grouped variables, Savings & cash flow, Financial credits, and Profitability, as shown in the diagram below.

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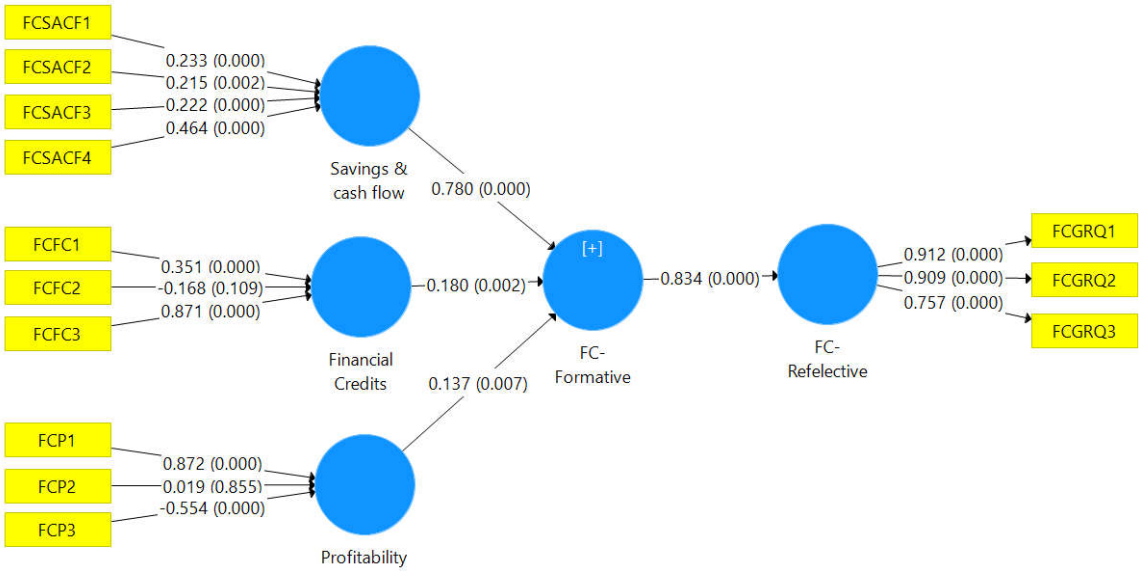

Figure 8. Path coefficient, significance, and relevance of Financial Capital variables.

Table 14. VIFs of Financial Capital Variables.

Inner Variable	***VIF***	***Inner Variable Continued***	***VIF***
Financial Credits		1.99FCP3	1.334
Profitability		1.512FCSACF1	2.2
Savings & cash flow		2.169FCSACF2	2.659
Outer Variables	***VIF***	FCSACF3	2.777
FCFC1		2.711FCSACF4	2.582
FCFC2		2.49FCP1	1.134
FCFC3		1.344FCP2	1.487

The output of the above analysis confirms applicability of the above indicators to define the financial capital construct contribution to SAP.

Physical Capital

Access to information, Availability & affordability of machinery, Infrastructure & availability of labour are the grouped variables identified for Physical capital assessment for this study. The following diagram and the Table depict the relevance of the indicators and the variables to explain the Physical capital contribution to SAP.

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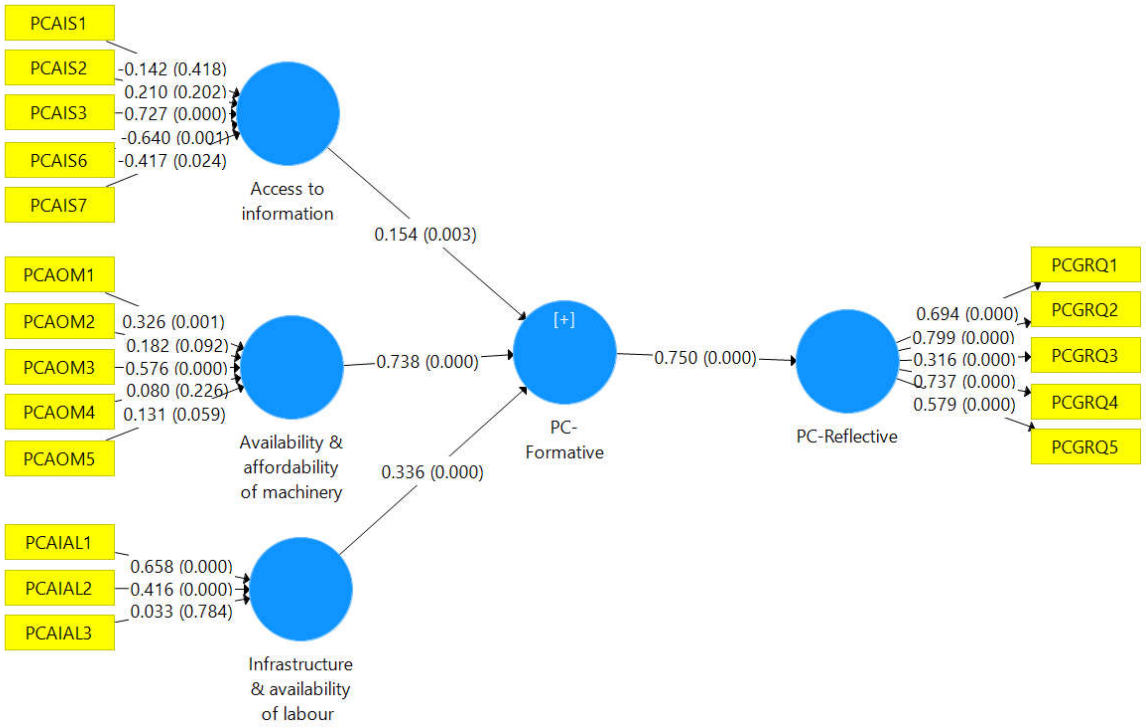

Figure 9. Path coefficient, significance, and relevance of Physical Capital variables.

Table 15. VIFs of Physical Capital Variables.

Inner Variable	*VIF*	*Outer Variable Continued*	*VIF*
Access to information	1.141	PCAIS6	2.35
Availability & affordability of machinery	1.273	PCAIS7	1.992
Infrastructure & availability of labour	1.286	PCAOM1	1.933
Outer Variable	***VIF***	PCAOM2	2.543
PCAIAL1	2.114	PCAOM3	1.78
PCAIAL2	1.77	PCAOM4	1.426
PCAIAL3	1.705	PCAOM5	1.381
PCAIS1	2.152	PCAIS3	1.294
PCAIS2	2.01		

Natural Capital

The natural Capital was assessed through 4 grouped variables: Soil fertility, Availability of carbonic substances, Waterworks & capacity of water, and Safety from natural disasters and animal attacks. The following figure and the Table show the indicators and grouped variables that satisfactorily define the NC construct of SAP.

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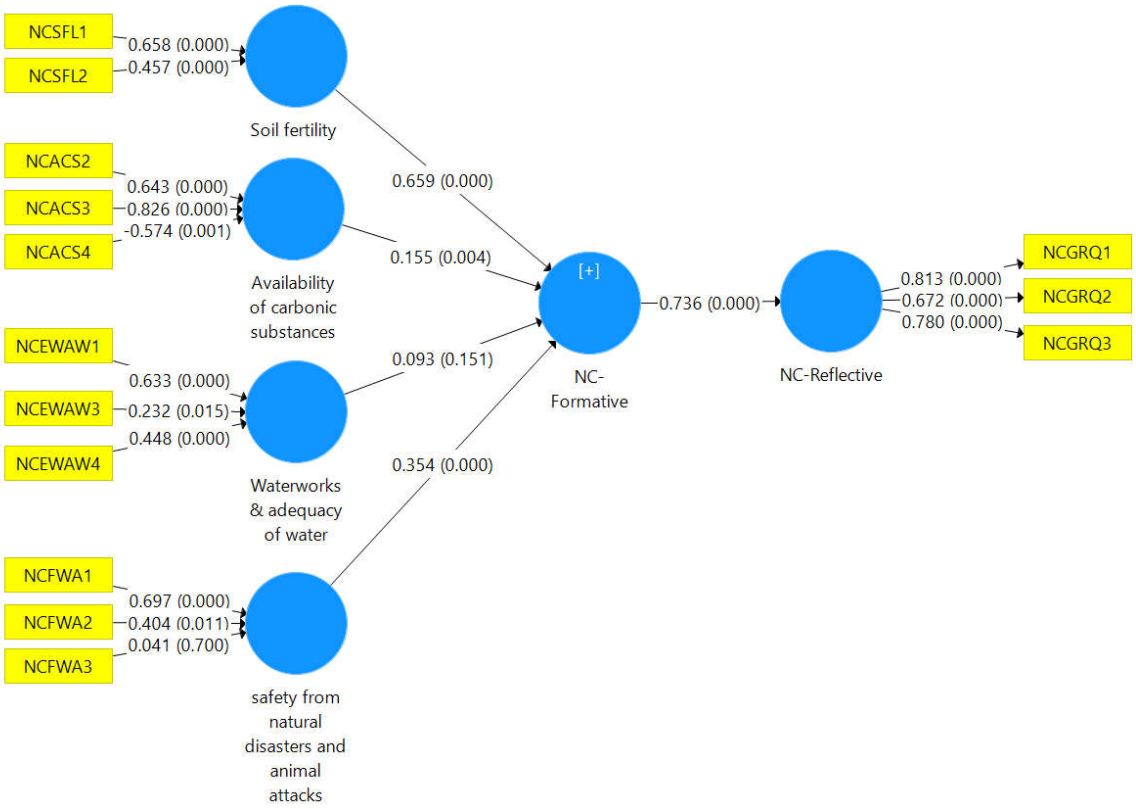

Figure 10. Path coefficient, significance, and relevance of Natural Capital variables.

Table 16. VIFs of Natural Capital Variables.

Inner Variable	*VIF*	*Inner Variable Continued*	*VIF*
Availability of carbonic substances		1.347NCEWAW4	1.16
Safety from natural & animal attacks safety from natural disasters and animal attacks		1.413NCFWA1	1.556
Soil fertility		1.5NCFWA2	1.582
Waterworks & adequacy of water		1.627NCFWA3	1.035
Outer variables	***VIF***	NCSFL1	1.542
NCACS2		2.17NCSFL2	1.542
NCACS3		2.658NCEWAW3	1.206
NCACS4		2.33NCEWAW1	1.21

Findings and Conclusion

This research aimed to scientifically define the constructs of farmers' SAP and find an acceptable set of indicators to measure those constructs. The exhaustive literature review on previous studies investigating farmers' SAP in various contexts helped derive a comprehensive list of indicators. The approach of compositely forming the constructs of SAP using formative quantitative indicators on a five-point Likert scale was found to be practical. The researcher believes that this approach comprehensively covered the dimension of each construct adequately since the long list of indicators was derived referring to more than 80 research articles continuing until the literature saturation was noticed. The dimension reduction approach (PCA) analysis available in PLS-SEM techniques on formative indicator analysis helped to filter out less productive questions from the lengthy Questionnaire. The follow-on survey of filtered questions using many samples proved the validity and integrity of the Questionnaire.

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Limitations of the study

The literature review carried out in a structured manner by subdividing the constructs is proven to cover broader coverage of dimensions of SAP. However, there is no way of practically proving that the process has not missed any applicable dimension. The researcher believes this set of indicators will get more refined and robust when researchers start adopting them for their research works in future. The dimension reduction (PCA) was carried out in a particular region of rice farming, and the results can vary from one region to another, particularly from the global perspective. However, the initial comprehensive Questionnaire is generic to many contexts because the researcher has considered 40 complete research studies from various parts of the world (USA-9, Europe-6, India-6, England-5, Nigeria-4, Sri Lanka-4, Tanzania-3, and South Africa-3) along with other reviews and concept papers related to the topic. The researchers can adopt this complete Questionnaire and customize it for individual needs following the process explained in this study. The questions in this Questionnaire are focused on rice cultivation; however, necessary alterations can be made to them to match the SA studies on other crops since there are more generic dimensions applicable to many. The five-point coding is adopted in this study since that was the practice seen in most similar research (Waseem et al., 2020; Mutyasira,2018; and Zahra, 2018). Alternatively, the researchers can reconsider the distance between scales and adjust the scales to lower or higher equal distances.

Conceptualizing the constructs and the set of indicators derived will be helpful for future researchers in SA studies, particularly in researching the nexus between farmers' SAP and their readiness to adopt organics, resilience to sudden farming conditions such as climate change, and adaptation to new approaches such as agro-tourism etc. Also, this research will provide a method for designing quantitative research using formative indicators, improving the predictive power of the constructs and hypotheses with optimum variance explained. Using measurement model analysis techniques in PLS-SEM can be insightful for researchers in such explorative studies. The model has provision to compare the regression weights of constructs that explain farmers' SAP and determine the areas for improvements. Also, the researchers can deep dive into the sub-dimensions and indicator levels of constructs to see which items are substantial and contributing more effectively to SAP, among others.

Annexe-1 – Indicators identified to measure Farmers' sustainable agriculture potential

Human Capital
Generic reflective questions (Scale of 1-5, SD-SA)
1. I am well motivated to continue with rice farming
2. I do get adequate labour for my rice farming activities
3. I know well about nature-friendly farming activities
4. I regularly apply nature-friendly farming activities in rice farming
5. I always use appropriate methods in my farming activities, adjusting to changing demands with the time
Formative questions (Scale of 1-5, SD-SA)
Health and well-being
6. I am living in perfect health condition
7. My household is also living in excellent health condition
8. It is infrequent our health issues impact our rice farming activities
9. I am well satisfied with my mental well-being
10. I am well satisfied with my relationships with friends
11. I am well satisfied with my relationships with my family
12. I am not worried at all about everything that is happening these days
13. I am optimistic about the next 12 months
14. I feel that the things I do in my life are worthwhile
15. I feel that the things I do in my life have the proper purpose
Knowledge and Farming Experiences

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16. I know the importance of water in rice farming and always use water optimally
17. I know the importance of soil fertility and continually preserving it
18. I know selecting a suitable seed is essential to improving profitability, and I am aware of them
19. I know how to minimize the chemical fertilizer while maintaining a good yield
20. I know the importance of utilizing organic compost
21. I know the irreversible consequences of neglecting irrigation on time
22. I know the importance of using pesticides according to the suggested specifications
23. I know biological methods to control pests effectively
24. I know the benefits of crop rotation, and such practice can increase soil fertility
25. I know the most effective method that can control weeds
26. I know the benefits of leaving crops residues in the field after harvest, and I always do so
27. I know that minimum tillage can reduce erosion and soil degradation
28. I know how to use the profitable planting method each season, and I do adapt
29. I know the benefits of the cultivation of legumes to improve soil fertility, and I use them
Planning and organizing
30. I do select profitable seeds in each season
31. I do select a suitable land plot for cultivation according to the season
32. I do the farming at the proper time
33. I do prepare the budget for every season to understand the costs and returns
34. I do keep and analyze production records for each season and usually analyze future production and trends
Attitudes
35. We must protect natural resources for the next generation even if it incurs short-term losses to our outturn
36. Still, I believe we can maintain good profits in rice farming with fewer chemical inputs
37. Intense use of chemicals in farming can negatively affects the health of people and animals
Beliefs and values
38. I believe that minimizing the use of chemicals is a timely need
39. Rice farming is my passion and not merely the job or my business
40. The yield produced through fewer chemicals is healthier
41. My farm plot is my biggest asset
42. I am always concerned about the preservation of my farm plot
43. My children/child will continue with our farming traditions

Social Capital
Generic reflective questions (Scale of 1-5, SD-SA)
(SA practices Example: Selecting better seeds for improved yield, minimizing chemical fertilizer use, improving soil fertility, minimum use of chemicals in pests and weed control, minimizing water waste and pollution, etc.)
44. I am living in a society where I am thoroughly encouraged to adopt SA practices
45. I am living in a society where I receive full support in adopting SA practices
46. I am living in a society where SA is considered an important
47. I will gain more social recognition if I adopt SA practices
Formative questions (Scale of 1-5, SD-SA)
Networks and connectedness, a) Bonding -similar individuals within a network, b) Bridging conservationists, c) Linkage -policymakers
48. Farmer organization provides me with significant help for my farming activities
49. I receive significant support from the community association of which I am a member of
50. I receive significant support from paddy buyers for my farming activities

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51. I receive significant support from agrochemical sellers for my farming activities
52. I receive significant support from various other goods and service suppliers for my farming activities
53. I receive significant support from agriculture researchers for my farming activities
54. I receive significant support from government officers for my farming activities
Trust and reciprocity- (SA practices Example: Selecting better seeds for improved yield, minimizing chemical fertilizer use, improving soil fertility, minimizing the use of chemicals in pests and weed control, minimizing water waste and pollution, etc.)
55. I trust the advice and support received from my fellow farmers on the above activities
56. I trust the advice and support received from government institutions (field officers) on the above activities
57. I trust the advice and support received from paddy buyers on the above activities
58. I trust the advice and support received from banks and other financial institutions
59. I trust the advice and support received from insurance companies on the above activities
60. I trust the advice and support received from agrochemical sellers on the above activities
Norms and values
61. Some fellow farmers compel me to more nature-friendly farming practices
62. I am always happy to produce harvest with higher standards
63. I will receive more social recognition if I adapt to more environmentally friendly farming methods
64. I will receive better price/demand if I produce paddy using organic matter and with less chemical use
Power
65. It is a condition of my land load to adapt the above practices
66. Paddy buyers give better rates to farmers who adopt those practices
67. Agro-Input sellers give discounts and credit facilities to farmers who adopt the above practices
68. I feel that government officials are becoming more supportive of the farmers who adopt the above practices
69. I find that wealthy farmers in our society support us in adapting the above practices

Financial Capital
Generic reflective questions (Scale of 1-5, SD-SA)
70. I am economically strong to continue with rice farming
71. Getting financial aid for my farming needs is not challenging
72. My rice farming is generally profitable
Formative questions (Scale of 1-5, SD-SA)
Savings and cash flow
73. Ensuring household food security is not a challenge for me
74. Meeting of other financial needs of my family is not a challenge for me
75. I do make a good surplus in each season
76. Re-investing in rice farming is not a challenge for me
Financial Credits
77. It is easy to take a loan from a bank
78. I can get loans quickly from other financial institutions
79. I can borrow money from local providers easily for a reasonable interest rate
Remittances
80. I receive substantial income from my other businesses
81. I have a regular job with a stable income, and rice farming is my part-time activity

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82.	Though rice farming is my main job, I do part-time jobs with good earning
83.	In addition to rice farming, I do other agriculture, which gives me a considerable income
84.	I receive regular income from my savings in the bank
Profitability	
85.	I get a fair price for my harvest, and the income is generally profitable
86.	The selling price keeps increasing in parallel with the cost increase of agro-inputs
87.	The profit I generate keeps increasing with the price increase of other household commodities

Physical Capital	
Generic reflective questions (Scale of 1-5, SD-SA)	
88.	I have the required machinery and equipment for rice farming
89.	I can afford to hire the machinery when needed
90.	I have access to SA agricultural knowledge
91.	I get market information easily
92.	I have easy access to agro-inputs selling outlets
Formative questions (Scale of 1-5, SD-SA)	
Availability of machinery	
(Types of machinery examples (Sprayer machine, water pump, two-wheeler tractor, four-wheeler tractor, planter, harvester, etc.)	
93.	I do possess required agricultural machinery and equipment needed for my farming
94.	Maintaining those types of machinery is not an issue for me
95.	I can afford to hire the above machinery whenever needed with no issues
96.	The charges I pay for the hiring of machinery are affordable
97.	The charges I pay for hiring machinery are reasonable
Access to information and consultancy services and market information (Printed, Radio, TV, and ICTs)	
98.	I listen to radio programs related to rice farming, and they are useful
99.	I watch television programs on rice farming, and they are useful
100.	I use my mobile phone to access rice farming information, and they are useful
101.	I use Internet (YouTube) videos on rice farming, and they are useful
102.	I use social media (Facebook) to watch videos on rice farming, and they are useful
103.	I read newspaper articles related to rice farming, and they are useful
104.	I regularly read the leaflet and broachers distributed on rice farming, and they are useful
Access infrastructure and availability of labour	
105.	It is easy to access the paddy buyers
106.	It is easy to access agriculture suppliers and vendors
107.	It is easy to find the labour required for rice farming activities

Natural Capital	
Generic reflective questions (Scale of 1-5, SD-SA)	
108.	I can improve the soil condition of my farm plot for organic fertilizer use
109.	I get an adequate water supply for my farming
110.	The location of my farm plot is less vulnerable to natural disasters
111.	The orientation of my farming plot supports the biological control of pests
112.	The orientation of my farming plot supports the biological control of weeds
Formative questions (Scale of 1-5, SD-SA)	
The soil fertility of the land	
(Observations: Sandiness, acidity, and colour)	

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113. I think the soil fertility of my farm plot is in good condition
114. I think I can improve the soil structure of my farm plot to enhance organic fertilizer use
115. The soil of my farm plot can retain wetness for a longer duration
Availability of carbonic substances to improve soil fertility
116. I can find unused, reasonable amounts of cow dung in the vicinity of my farm plot
117. I can find reasonable amounts of poultry manure in the vicinity of my farm plot
118. I can prepare the compost required for my farm plot
119. I can find a good amount of green manure crop in the vicinity of my farm plot
Effectiveness of waterworks and adequacy of water
120. The waterworks to my farm plot is well maintained
121. I am satisfied with the timing of the water releases from managed irrigation networks
122. I can rely on rainwater, too, to a reasonable extent
123. I can pump water to my plot if required
Ability to control (Pests, insects, fungi, and weeds) naturally
124. I use fewer chemicals in controlling pests compared to others
125. I use fewer chemicals in controlling insects compared to others
126. I use fewer chemicals in controlling fungus compared to others
127. I use fewer chemicals in controlling weeds compared to others
Frequencies of weather extremes and animal attacks
128. I am not facing severe crop damage due to drought
129. I am not facing severe crop damage due to floods
130. I am not facing severe crop damage due to animal attacks

Annex-2 -Outcomes of Measurement analysis pilot survey

Exabit 01- Assessment of Convergent validity – Human Capital

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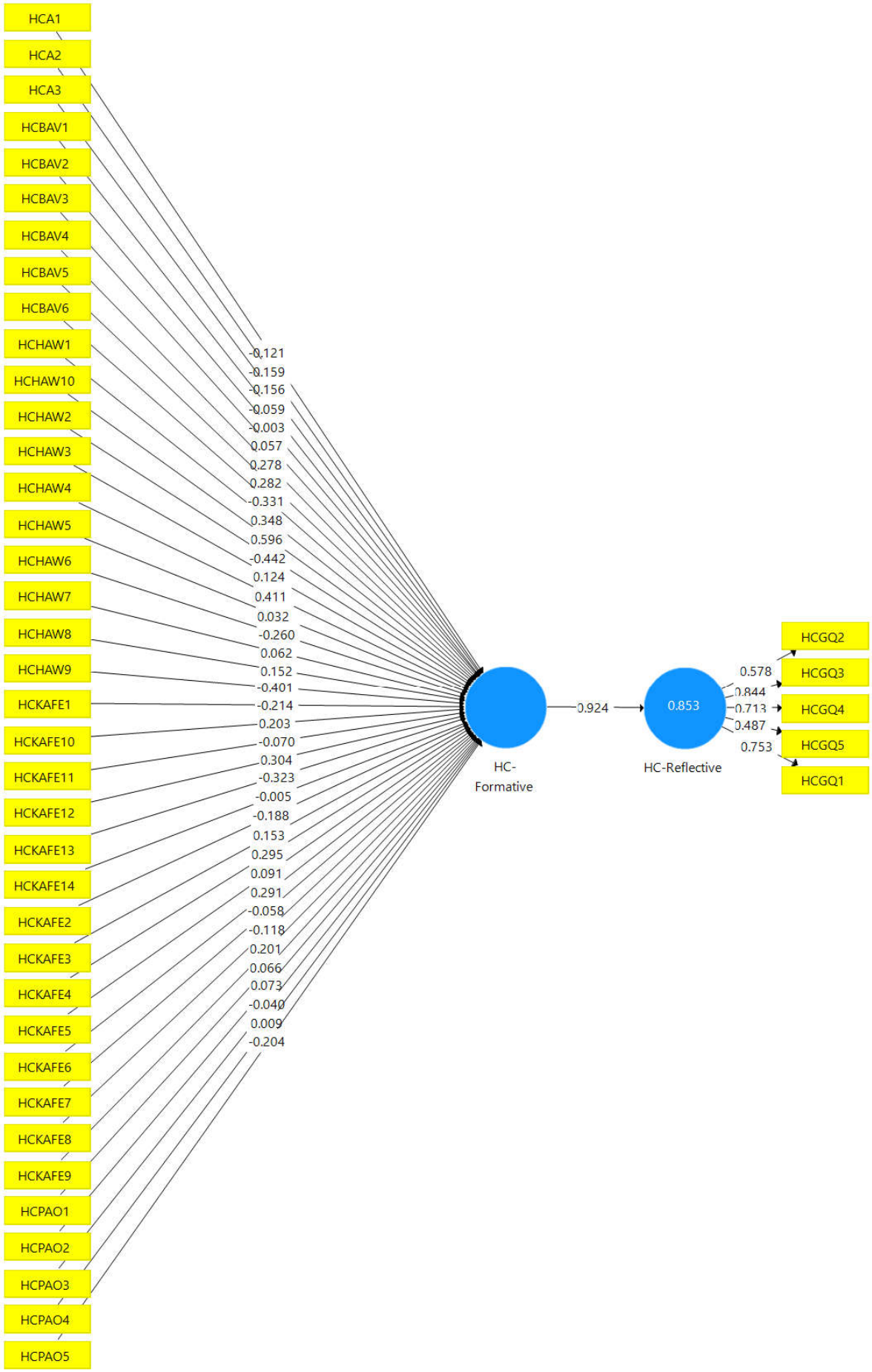

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Table 01. – Redundancy Analysis -Human Capital.

Collinearity Statistics		Outer Weights			Outer Loading		
Indicator	VIF	Std. Deviation	T Statistics	P Values	Std. Deviation	T Statistics	P Values
HCA1	2.316	2.22	0.054	0.957	0.127	0.922	0.357
HCA2	3.902	1.738	0.091	0.927	0.128	0.413	0.68
HCA3	3.144	1.621	0.096	0.923	0.122	1.544	0.123
HCBAV1	3.011	2.564	0.023	0.982	0.112	1.678	0.094
HCBAV2	2.039	2.269	0.001	0.999	0.129	0.071	0.943
HCBAV3	2.338	1.394	0.041	0.967	0.126	2.313	0.021
HCBAV4	7.576	3.843	0.072	0.942	0.122	2.749	0.006
HCBAV5	5.201	2.536	0.111	0.911	0.089	5.565	0
HCBAV6	4.704	2.43	0.136	0.892	0.13	2.513	0.012
HCGQ2	1.355	0.047	4.768	0	0.116	4.991	0
HCGQ3	1.889	0.028	13.515	0	0.028	30.593	0
HCGQ4	1.546	0.031	9.387	0	0.083	8.547	0
HCGQ5	1.145	0.061	3.805	0	0.146	3.343	0.001
HCHAW1	7.024	4.188	0.083	0.934	0.119	4.077	0
HCHAW10	6.871	2.879	0.207	0.836	0.115	3.595	0
HCHAW2	5.578	3.787	0.117	0.907	0.132	2.119	0.034
HCHAW3	4.245	2.153	0.058	0.954	0.137	2.099	0.036
HCHAW4	6.806	3.605	0.114	0.909	0.097	6.786	0
HCHAW5	4.296	1.785	0.018	0.986	0.123	3.355	0.001
HCHAW6	5.298	3.104	0.084	0.933	0.118	2.582	0.01
HCHAW7	2.101	2.006	0.031	0.975	0.127	2.267	0.024
HCHAW8	3.695	2.828	0.054	0.957	0.111	4.232	0
HCHAW9	5.906	2.48	0.162	0.872	0.138	2.585	0.01
HCKAFE1	11.956	3.802	0.056	0.955	0.121	2.644	0.008
HCKAFE10	4.945	3.016	0.067	0.946	0.093	6.789	0
HCKAFE11	6.713	2.901	0.024	0.981	0.092	5.866	0
HCKAFE12	5.548	2.452	0.124	0.901	0.086	6.785	0
HCKAFE13	11.873	4.326	0.075	0.941	0.074	8.482	0
HCKAFE14	6.849	3.237	0.002	0.999	0.121	4.007	0
HCKAFE2	6.545	4.157	0.045	0.964	0.121	2.601	0.009
HCKAFE3	12.714	4.694	0.033	0.974	0.122	3.226	0.001
HCKAFE4	5.445	2.294	0.129	0.898	0.134	1.927	0.054
HCKAFE5	3.77	2.548	0.036	0.972	0.108	4.559	0
HCKAFE6	4.641	2.232	0.13	0.896	0.1	6.542	0
HCKAFE7	5.091	2.604	0.022	0.982	0.105	4.475	0
HCKAFE8	4.393	2.882	0.041	0.967	0.134	3.79	0
HCKAFE9	9.668	4.181	0.048	0.962	0.077	9.036	0
HCPAO1	7.69	4.005	0.017	0.987	0.143	2.823	0.005
HCPAO2	6.215	3.323	0.022	0.983	0.131	3.235	0.001
HCPAO3	4.743	3.009	0.013	0.989	0.127	2.783	0.005
HCPAO4	9.484	3.22	0.003	0.998	0.117	1.955	0.051
HCPAO5	6.531	2.558	0.08	0.936	0.126	1.562	0.119
HCGQ1	1.519	0.032	9.468	0	0.067	11.245	0

Exabit 02- Assessment Convergent validity – Social Capital

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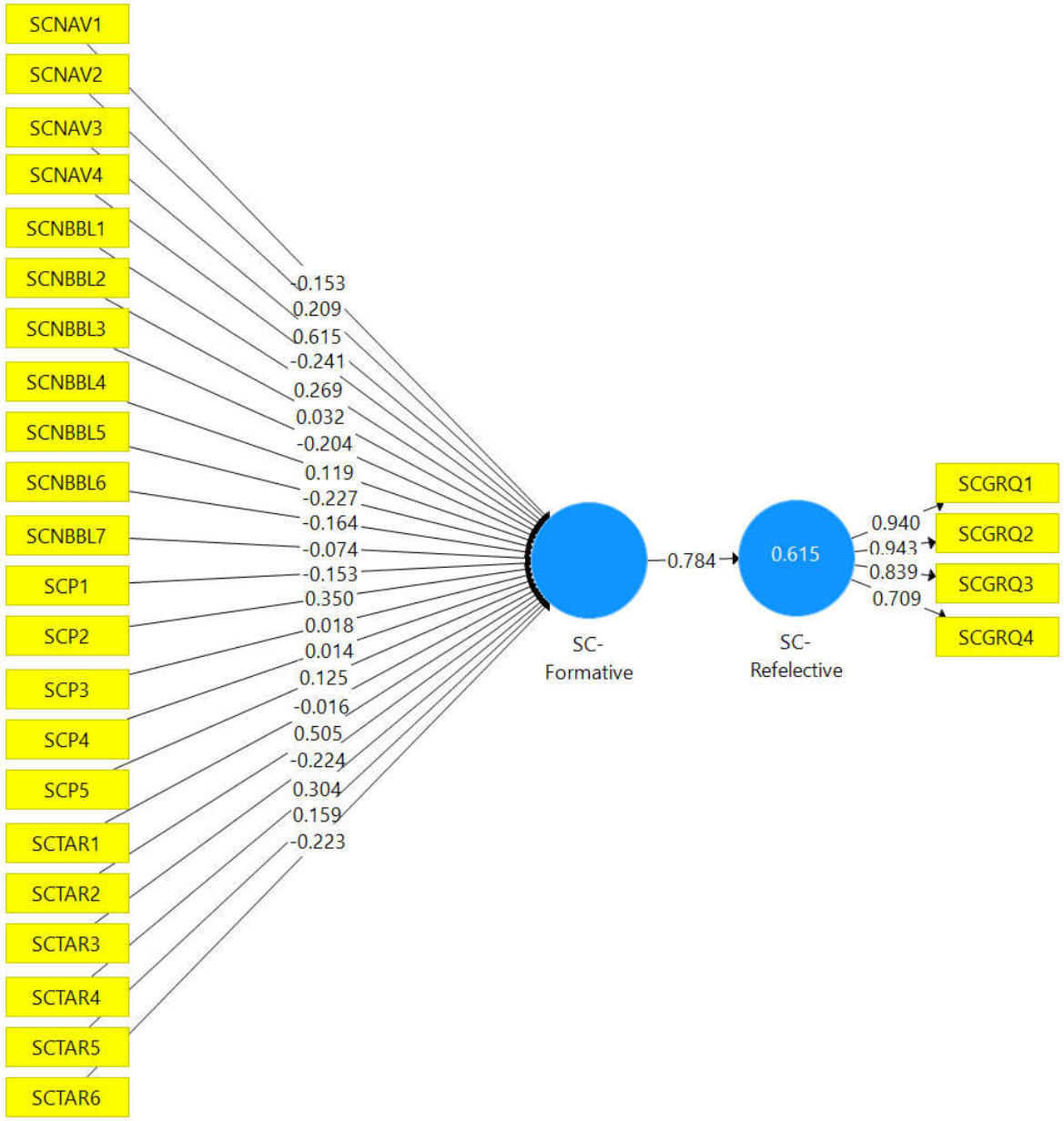

Table 02. – Redundancy Analysis -Social Capital.

Collinearity statistics		Outer Weight			Outer Loading		
Indicator	VIF	Std. Deviation	T Statistics	P Values	Std. Deviation	T Statistics	P Values
SCGRQ1	6.434	0.021	14.89	0	0.017	56.434	0
SCGRQ2	6.326	0.023	14.818	0	0.016	59.27	0
SCGRQ3	2.271	0.024	10.392	0	0.052	16.103	0
SCGRQ4	1.448	0.04	6.025	0	0.12	5.902	0
SCNAV1	2.004	0.219	0.699	0.485	0.155	2.67	0.008
SCNAV2	2.007	0.239	0.876	0.381	0.149	0.813	0.416
SCNAV3	2.671	0.233	2.644	0.008	0.124	5.14	0
SCNAV4	2.262	0.213	1.129	0.259	0.138	1.564	0.118
SCNBBL1	2.553	0.294	0.915	0.36	0.124	3.775	0
SCNBBL2	3.078	0.246	0.131	0.895	0.125	0.547	0.585
SCNBBL3	4.003	0.338	0.605	0.545	0.143	0.012	0.99
SCNBBL4	3.971	0.336	0.354	0.723	0.126	0.107	0.915

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SCNBBL5	2.686	0.254	0.895	0.371	0.128	0.252	0.801
SCNBBL6	4.732	0.29	0.566	0.571	0.143	2.441	0.015
SCNBBL7	7.757	0.327	0.226	0.821	0.123	4.342	0
SCP1	2.433	0.228	0.67	0.503	0.094	2.068	0.039
SCP2	2.401	0.241	1.451	0.147	0.116	4.768	0
SCP3	3.621	0.285	0.064	0.949	0.107	4.242	0
SCP4	3.55	0.258	0.055	0.956	0.121	4.679	0
SCP5	3.36	0.251	0.5	0.617	0.083	7.132	0
SCTAR1	1.747	0.228	0.069	0.945	0.147	1.198	0.231
SCTAR2	5.336	0.331	1.525	0.127	0.117	4.618	0
SCTAR3	4.077	0.321	0.698	0.485	0.14	0.187	0.852
SCTAR4	2.635	0.3	1.012	0.312	0.169	1.845	0.065
SCTAR5	3.071	0.235	0.674	0.5	0.103	4.808	0
SCTAR6	3.696	0.287	0.777	0.437	0.133	0.94	0.347

Exabit 03- Assessment Convergent validity – Financial Capital

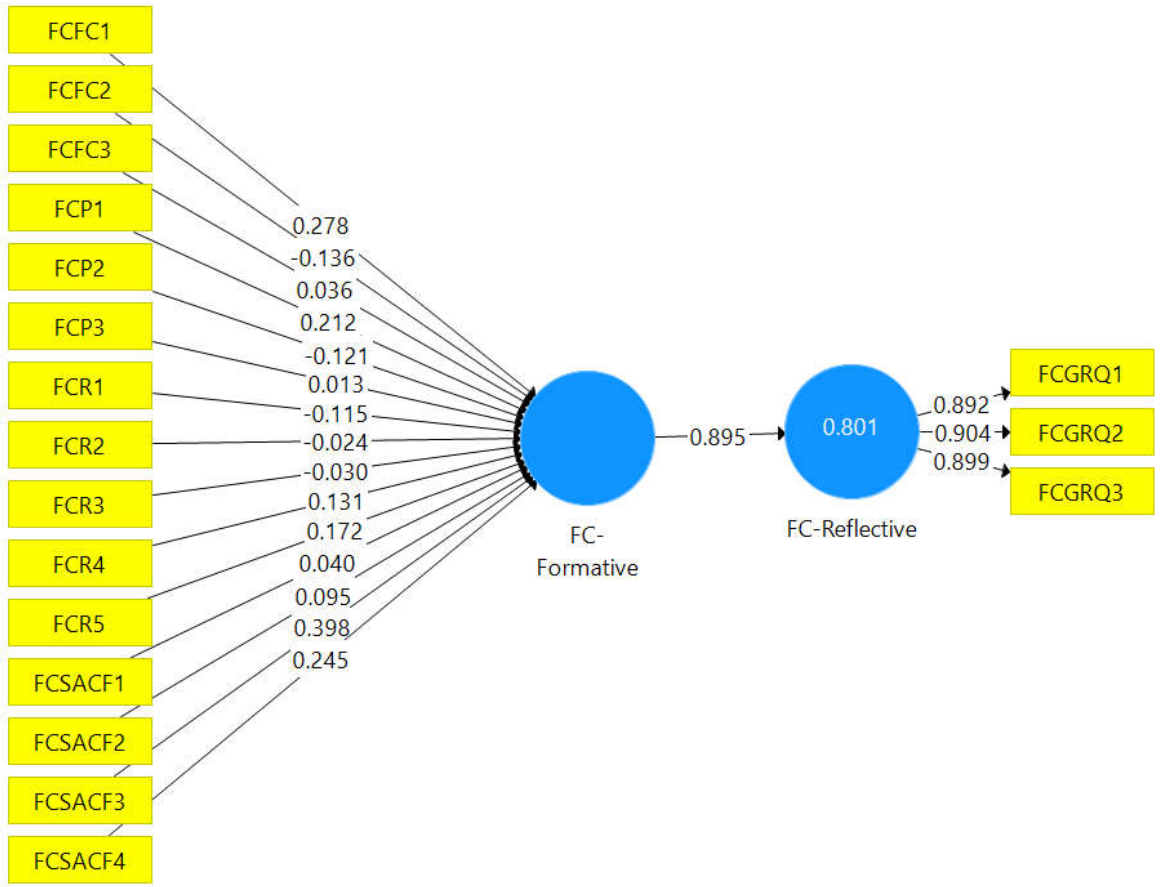

Table 03. – Redundancy Analysis -Financial Capital.

Collinearity statistics		Outer Weight			Outer Loading		
Indicator	VIF	Std. Deviation	T Statistics	P Values	Std. Deviation	T Statistics	P Values
FCFC1	6.562	0.234	1.189	0.235	0.075	9.144	0
FCFC2	6.239	0.244	0.557	0.578	0.09	6.621	0
FCFC3	2.242	0.127	0.282	0.778	0.117	4.577	0
FCGRQ1	2.394	0.018	19.569	0	0.031	28.755	0
FCGRQ2	2.461	0.018	21.112	0	0.029	30.65	0

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FCGRQ3	2.462	0.018	20.943	0	0.033	27.469	0
FCP1	2.207	0.145	1.466	0.143	0.077	9.118	0
FCP2	2.132	0.11	1.097	0.273	0.114	4.122	0
FCP3	2	0.126	0.106	0.916	0.135	3.046	0.002
FCR1	2.909	0.16	0.718	0.473	0.13	3.618	0
FCR2	1.583	0.096	0.248	0.804	0.131	0.051	0.959
FCR3	2.834	0.135	0.225	0.822	0.147	1.114	0.265
FCR4	2.752	0.136	0.963	0.335	0.111	4.921	0
FCR5	2.663	0.13	1.317	0.188	0.116	4.755	0
FCSACF1	2.273	0.112	0.357	0.721	0.099	6.477	0
FCSACF2	3.561	0.159	0.601	0.548	0.086	8.922	0
FCSACF3	3.541	0.177	2.245	0.025	0.053	17.066	0
FCSACF4	3.882	0.16	1.529	0.126	0.061	14.185	0

Exabit 04- Assessment Convergent validity – Physical Capital

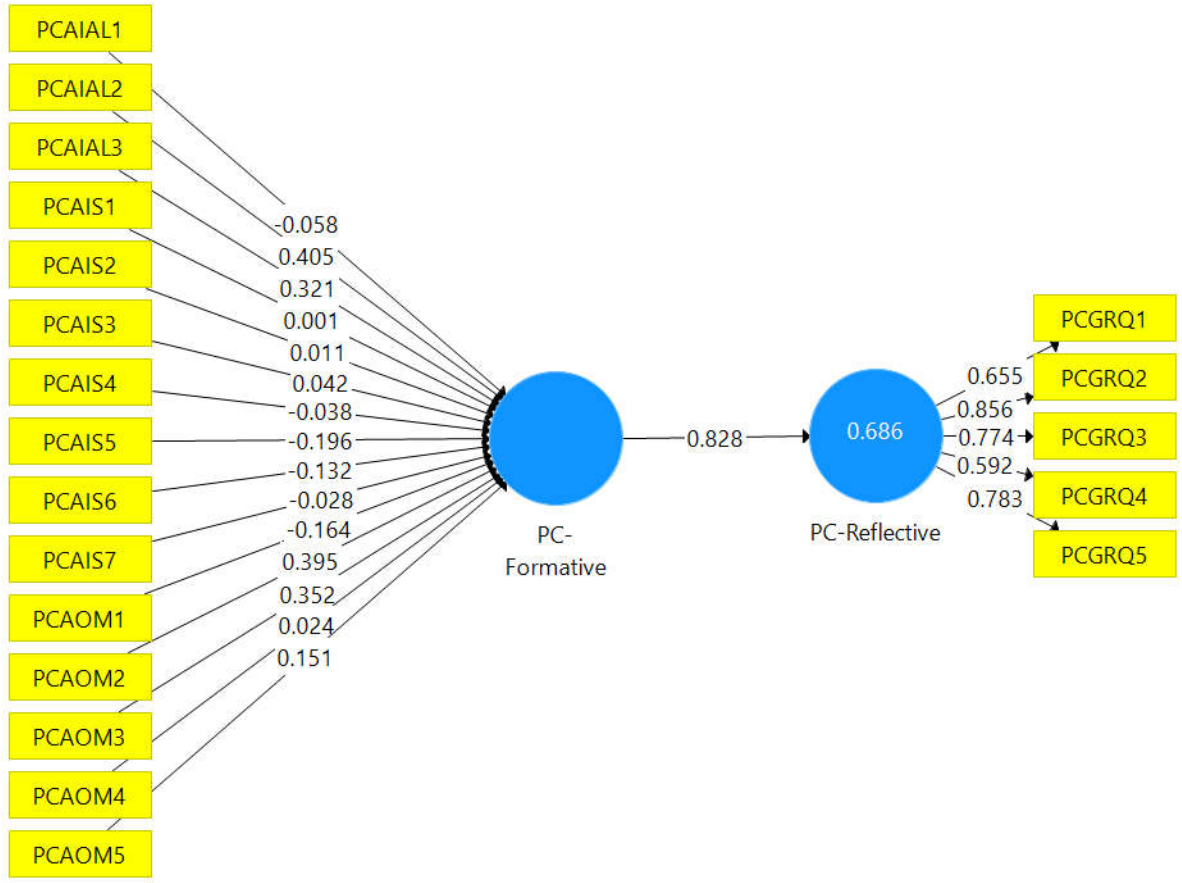

Table 04. – Redundancy Analysis -Physical Capital.

Collinearity statistics		Outer Weight			Outer Loading		
Indicator	VIF	Std. Deviation	T Statistics	P Values	Std. Deviation	T Statistics	P Values
PCAIAL1	3.437	0.334	0.175	0.861	0.176	3.379	0.001
PCAIAL2	3.797	0.34	1.191	0.234	0.14	5.333	0
PCAIAL3	1.953	0.16	2.002	0.045	0.12	5.008	0
PCAIS1	2.556	0.166	0.006	0.995	0.167	0.083	0.934
PCAIS2	3.618	0.238	0.048	0.962	0.162	0.236	0.814
PCAIS3	8.064	0.354	0.12	0.905	0.147	0.134	0.893

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PCAIS4	7.524	0.354	0.109	0.914	0.15	0.32	0.749
PCAIS5	4.176	0.372	0.528	0.598	0.157	0.211	0.833
PCAIS6	3.793	0.293	0.449	0.653	0.146	0.753	0.451
PCAIS7	2.761	0.192	0.145	0.885	0.148	0.547	0.584
PCAOM1	3.407	0.242	0.68	0.497	0.159	2.626	0.009
PCAOM2	4.455	0.287	1.375	0.169	0.115	4.904	0
PCAOM3	2.794	0.221	1.594	0.111	0.077	10.797	0
PCAOM4	3.191	0.193	0.122	0.903	0.091	7.149	0
PCAOM5	1.951	0.151	1.005	0.315	0.128	2.931	0.003
PCGRQ1	1.481	0.039	6.1	0	0.086	7.61	0
PCGRQ2	2.375	0.038	8.334	0	0.054	15.82	0
PCGRQ3	1.764	0.034	8.22	0	0.081	9.577	0
PCGRQ4	1.445	0.064	2.703	0.007	0.154	3.85	0
PCGRQ5	1.912	0.041	7.915	0	0.069	11.312	0

Exabit 05- Assessment Convergent validity – Natural Capital

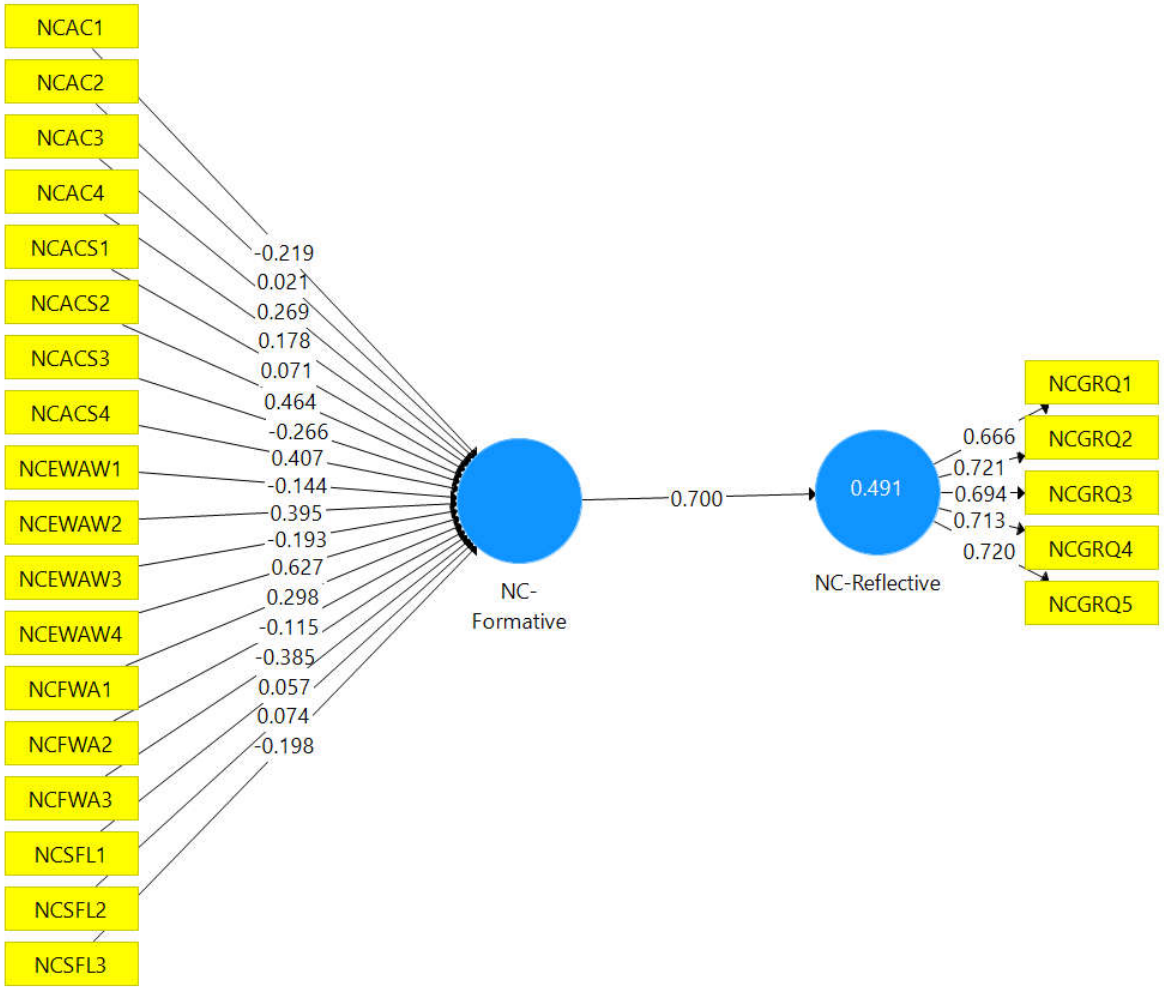

Table 05. – Redundancy Analysis -Natural Capital.

Collinearity statistics		Outer Weight			Outer Loading		
Indicator	VIF	Std. Deviation	T Statistics	P Values	Std. Deviation	T Statistics	P Values
NCAC1	10.226	40.198	0.005	0.996	0.149	2.506	0.012
NCAC2	9.509	0.804	0.026	0.979	0.151	2.63	0.009
NCAC3	19.538	58.429	0.005	0.996	0.149	2.694	0.007

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NCAC4	9.909	20.203	0.009	0.993	0.141	2.896	0.004
NCACS1	6.394	0.406	0.175	0.861	0.129	4.67	0
NCACS2	5.078	0.322	1.442	0.15	0.121	4.742	0
NCACS3	2.944	0.282	0.943	0.346	0.151	3.344	0.001
NCACS4	2.972	0.273	1.49	0.137	0.14	4.179	0
NCEWAW1	3.675	0.342	0.42	0.675	0.138	4.752	0
NCEWAW2	3.785	0.304	1.301	0.194	0.146	3.807	0
NCEWAW3	2.467	0.269	0.719	0.472	0.151	2.651	0.008
NCEWAW4	3.599	0.307	2.044	0.041	0.131	4.926	0
NCFWA1	2.182	0.248	1.204	0.229	0.187	0.905	0.365
NCFWA2	2.644	0.266	0.433	0.665	0.194	0.651	0.515
NCFWA3	2.811	0.313	1.228	0.22	0.182	0.853	0.394
NCGRQ1	1.318	0.084	3.747	0	0.138	4.831	0
NCGRQ2	1.5	0.066	5.495	0	0.102	7.065	0
NCGRQ3	1.637	0.079	2.721	0.007	0.142	4.871	0
NCGRQ4	2.719	0.066	3.904	0	0.115	6.172	0
NCGRQ5	2.76	0.071	3.814	0	0.12	6.025	0
NCSFL1	1.799	0.206	0.278	0.781	0.164	2.297	0.022
NCSFL2	2.397	0.284	0.259	0.795	0.193	2.111	0.035
NCSFL3	1.621	0.207	0.955	0.34	0.157	0.117	0.907

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