Volume 32 Issue 1 June 2022

Asia-Pacific Journal of Rural Development

SAGE

Los Angeles | London | New Delhi
Singapore | Washington DC | Melbourne

Aims and Scope

Asia-Pacific Journal of Rural Development is a peer-reviewed journal that provides a platform for publication of articles in all areas of rural development. The aim of this journal is to provide a platform for policy makers and academicians to promote, share and discuss various new issues and developments in different areas of rural development. The journal publishes conceptual, empirical and review papers in the form of research articles, reports of ongoing research, analyses of current and topical practice, policy issues relating to rural development field notes and book reviews. The journal is peer-reviewed and adheres to a rigorous double-blind reviewing policy in which the identity of both the reviewer and author are always concealed from both parties.

Subject areas include any thematic areas related to sustainable integrated rural development aligned with Sustainable Development Goals (SDGs). The thematic areas are including but not limited to the following:

- Sustainable use of natural resources
- Management of rural areas in transition
- Land and water resources management
- Agro processing and rural market
- Rural livelihoods and poverty reduction
- Education and skill development
- Entrepreneurship and financial inclusion
- Climate change
- Local governance
- Food and nutrition
- Health and hygiene
- ICT and geospatial technology for rural development
- Renewable energy for rural consumption
- Rural transportation
- Sustainable rural tourism

Asia-Pacific Journal of Rural Development

Asia-Pacific Journal of Rural Development

Volume 32 Issue 1 June 2022

Contents

Articles

Case Study

Field Note

Article

Assessment of Natural Capital for Sustainable Rural Livelihoods: An Empirical Study of Mizoram, India

Asia-Pacific Journal of Rural Development
32(1) 7–25, 2022

DOI: 10.1177/10185291221114684
journals.sagepub.com/home/jrd
SAGE

Vishwambhar Prasad Sati[1]

Abstract

The state of Mizoram has plenty of natural capital in the form of a feasible climate, rich forest, an abundance of water and rich agroecological conditions. However, this capital is not exploited optimally to help the rural people plagued by acute food insecurity there. This study assesses the potential of the natural capital there for creating sustainable rural livelihoods in Mizoram. The analysis has been performed based on the case studies conducted in 16 villages, 2 villages from each district. A total of 1,527 households were surveyed using a purposive random sampling method. A structured questionnaire was designed where the questions were asked to gather information on climate conditions, forests, water and agriculture. The findings reveal that the optimum use of natural capital will enhance rural livelihoods substantially. Tourism development, the establishment of forest-based small-scale industries in rural areas, rainwater harvesting, construction of micro hydroelectricity power projects, and cultivation of diverse crop races/cultivars, including food grains, vegetables and fruits, along with systematic rice intensification in the suitable agroecological zones can bring a momentum to expedite rural livelihoods there.

Keywords

Natural capital, rural livelihood, tourism development, forest products, agroecology, Mizoram State of India

Introduction

Natural capital consists of the natural environment/resources (Edward, 2019). Natural capital, the stock of natural assets of the world, includes geology, soil, air,

[1] Department of Geography and Resource Management, Mizoram University, Aizawl, Mizoram, India

Corresponding author:
Vishwambhar Prasad Sati, Department of Geography and Resource Management, Mizoram University, Aizawl, Mizoram 796004, India.
E-mail: sati.vp@gmail.com

forest, water and all living things in the world. Humans derive numerous services from natural capital, which is often called ecosystem services (CBD, 2021). These services help in carrying out livelihood activities sustainably and thus make human life comfortable. Food, plants, air and water are the most important substances of natural capital on which life is dependent. Further, these natural capitals provide some invisible services such as carbon sequestration and pollination (Sun & Dong, 2007). Natural capitals worldwide are passing through two phases. The first one is their overexploitation, which has led to catastrophes. Many world countries have attained the developed stage and they have overexploited natural capitals. The second one is the underutilization of natural capital. The underdeveloped and developing countries could not utilize the natural capitals because of lacking assessment of these capitals or lacking infrastructural facilities to use them sustainably. Management is another aspect. Poor management of natural capital has become both ecological and social liability (Gong et al., 2012). People suffer from malnutrition and food scarcity because of the underuse of natural capital (Amir-ud-Din et al., 2017). Therefore, the optimum use of natural capital will enhance food security and the socio-economic well-being of people (Daily et al., 2013; Hanjra et al., 2017; Natural Capital Committee, 2015; Sati & Vangchhia, 2018).

Climatic conditions set the stage for economic development through flourishing tourism, encouraging afforestation, maintaining air and water quality, and sustaining health conditions. These are some of the major sources of livelihood activities. As stated above, timber and non-timber-based forest products (NTFP) are physical capital, upon which the rural livelihood is dependent, mainly in the developing world (Adam et al., 2013). Water quality and its abundant supply provide a foundation for the sustenance of livelihoods. It is used not only for drinking and domestic purposes but also used for irrigation, which is essential for increasing crop production and productivity. Agriculture which is based on land resources, one of the major natural capitals, plays an important role in sustainable rural livelihoods (Acharya, 2006). Many countries in the world, especially in the developing world, use agriculture as their main occupation and the major source of livelihood for a large number of people. However, its mode is traditional and its output is relatively less than other sources of livelihood. In the recent past, agricultural production and productivity have decreased, due to several factors one of which is climate change (Aase et al., 2009; Cline, 2008; Huddleston et al., 2003; IPCC, 2007; UNDP, 2006). In the Himalayan region, there are several other reasons, which have impacted agricultural production and productivity (ICIMOD, 1996; Tiwari & Joshi, 2011, 2012; Tscharntke et al., 2012).

Mizoram is an economically underdeveloped state in India (Niti Aayog, 2018). The livelihood of the people is dependent on agriculture, livestock and the collection of forest products. Agriculture is characterized by both shifting and wet rice cultivation (WRC). Due to low productivity from shifting cultivation, the area under it decreased by 58%, while, under WRC, it increased by 13.6% from 1996 to 2018. About 54% of rural people are engaged in practising shifting cultivation in Mizoram. By 2000, approximately 58,000 households were engaged

in practising shifting cultivation (Maithani, 2005). In the meantime, this figure was reported as 50,000 by the Govind Ballabh Pant National Institute of Himalayan Environment. The marginal farmers, who are known as *Jhumias*, are still practising shifting cultivation substantially even though crop production and productivity are being decreased over time.

Mizoram is facing food insecurity because of inadequate production of food and thus the consequent lower level of income. The lower production and productivity of shifting cultivation are not sufficient to meet the food requirement of rural people. Obviously, a low level of productivity brings in a low level of income. A lower level of income restricts the capability to purchase food from other states unless the lower level of income from shifting cultivation is supplemented by other sources of income. As a result, about 33% of the people there were living below the poverty line and about 17% of people were living in chronic poverty (State Statistical Handbook, 2017). The infant mortality rate was 200 in Saiha, the southernmost district of Mizoram (Sati & Vangchhia, 2016). About 52% of the people live in urban areas (COI, 2011).

The state of Mizoram is perceived to have plenty of natural capital in the form of forests with rich biodiversity, feasible climate, sound environment and rich agroecology. Policy intervention for the optimal utilization of natural capital may lead to sustainable rural livelihoods in India. Several studies on various aspects of natural capital have been conducted from time to time by scholars in India (FAO, 2017; Leblhuber & Vanlalhruaia, 2012; Maithani, 2005; Ramakrishnan, 1992; Raman, 2001). However, there were no systematic studies carried out on the assessment of physical capitals, in terms of their availability, potentiality and contribution to rural livelihoods. The main objective of this study is to assess the availability of natural capital in Mizoram, examine the potential of natural capital in sustaining rural livelihoods, and suggest policy measures for the sustainable use of natural capital in Mizoram.

Methodology

Study Area

Mizoram, a tiny and hilly state, is located in northeast India, known as the eastern extension of the Himalaya. Its total geographical area is 21,081 km^2 of which, 97% is undulating, rugged and precipitous hills. Mizoram possesses plenty of natural capital/assets in the forms of forests, water, land and a feasible climate. Forests cover 86% area with rich biodiversity (FSI, 2019). The rivers are perennial and contribute to the major portion of water. The suitable climate, rich environmental quality and spectacular landscape support tourism development here. Agriculture is the main occupation and the major source of livelihood. However, arable land is only 5.5% of the total geographical area of which shifting cultivation has 16.9% area in 2017–18. Further, shifting cultivation has decreased about 71.22% during the last three decades (State Statistical Handbook, 2017).

Rice is the staple food that meets 33% of the state requirement. Rice is produced under shifting cultivation and WRC. It seems that these abundant natural capitals are not harnessed adequately and sustainably. Mizoram has a 1.92 million population with 52 persons living per sq km of which 54% live in rural areas that are fully dependent on the natural capital mainly on agricultural outputs. Besides agriculture, livestock and forestry are the other sources of livelihood. The population size of 16 case-studied villages was 582 (mean value) with a maximum of 3,282 and a minimum of 170 population. The sex ratio was 956 females/1000 males. It varied from 1,300 (maximum) to 857 (minimum) female/thousand male in 2018.

Data and Survey

This study was conducted between July and October 2018 through a case study of 16 villages from eight districts of Mizoram state, two villages from each district. The household-level survey was conducted using a purposive random sampling method. Of the total 2010 households in the survey area, 1,527 (76%) households were selected. A structured questionnaire was designed based on different questions on natural capital—climate, forests, water and agriculture crops—area, production and productivity. Data on income and expenditure at the household level were collected. Data were collected in 2000 by recall method and in 2018 immediately. The average age of the respondent was 52 years and they all had 10th or 12th years of education. They were able to recall 2000 agricultural data. Geographical data such as latitudes, longitudes, altitudes and accessibility of villages from the road (Table 1) were collected by using Geographical Positioning System (GPS). Village level data on terrain, climate, soils and forests were collected during the field visits. The altitude of villages varies from 118 m (Saihapui K) to 1,513 m (Tualcheng). Hmuifang village is the second highest with a 1,472 m altitude. There are a total of four villages, which are situated below 500 m altitudes, four villages are situated between 500 m and 1,000 m altitudes, and eight villages are situated above 1,000 m altitudes. Mizoram has very poor road connectivity, and thus many villages are remotely located. Village E. Saizawh has been located 60 km from the main road. Thlengang, Pamchung and Bawnthah villages have more than a 20 km distance from the main road. The seven villages are located on the road and others are situated up to 10 km from the road.

Based on the objectives of the study, both qualitative and quantitative methods were used. The collected data on different natural capitals were analysed using various statistical methods and their potential was estimated. The climate data—rainfall and temperature were analysed using a linear regression model. The area, production and productivity of principal crops of 16 villages were analysed and changes in all variables were noted between 2000 and 2018. The mean value and standard deviation of all the principal crops were found. A correlation between altitude, accessibility and productivity was established. Data were shown using graphs and diagrams.

Table 1. Geographical Indicators and Village-Wise Households in the Study Villages.

Villages	Latitude (N)	Longitude (E)	Altitude (m)	Distance from Road	Number of HHs	Surveyed HHs	Surveyed HHs (%)
Ahmypi	23°43′24"	93°30′42"	1,043	0	42	37	88.1
Bawngthah	23°43′74"	93°23′44"	800	24	74	74	100
Chekkawn	23°48′58"	92°45′53"	907	0	49	47	95.90
Chhumkhum	23°44′24"	92°75′86"	286	0	53	53	100
E. Saizawh	23°53′23"	92°40′44"	358	60	107	81	75.7
Hmawngkawn	24°16′29"	92°38′02"	1,218	7	36	36	100
Hmuifang	23°49′26"	92°49′23"	1,472	0	62	62	100
Lengpui	23°18′16"	93°18′19"	412	0	735	519	70.6
Mualkhang	22°49′21"	92°36′11"	507	7	106	65	61.3
Nausel	22°40′21"	92°54′42"	946	4	61	53	86.9
Old Tisopi	22°40′29"	92°59′44"	1,182	10	35	35	100
Pamchung	22°21′56"	92°49′56"	1,167	20	63	57	90.5
Rawlbuk	22°21′56"	93°01′64"	1,201	0	119	119	100
Saihapui K	22°33′19"	92°59′35"	118	0	266	114	42.9
Thlengang	23°13′28"	92°36′27"	1,094	21	45	39	86.9
Tualcheng	23°50′18"	92°37′13"	1,513	12	157	136	86.6
Total					2,010	1,527	76

Source: The author.

Results and Discussion

Characteristics of Physical Capital in Selected Villages

Characteristics of physical capital—four variables—terrain, climate, soils and forest types of the study villages were illustrated (Table 2). There are three types of landscapes—plains, gentle slopes and steep slopes. The highest number of villages is situated on steep slopes, as more than 97% area of Mizoram is hilly with rough, rugged and precipitous slopes. Climatic conditions of the villages are quite feasible except for a few ones, which are situated in the valley regions. The

Table 2. Characteristics of Physical Capital of Selected Villages.

Village	Terrain	Climate	Soils	Forest Types
Ahmypi	Steep slope	Moderate warm	Clayey	Dense mixed bamboo
Bawngthah	Steep slope	Moderate	Red, stony	Dense mixed bamboo
Chekkawn	Steep slope	Moderate	Clayey	Evergreen
Chhumkhum	Gentle slope	Moderate warm	Swampy clayey	Mixed bamboo, evergreen
E. Saizawh	Gentle slope	Moderate warm	Swampy	Thick evergreen
Hmawngkawn	Steep slope	Moderate	Clayey	Dense tropical evergreen
Hmuifang	Steep slope	Cold	Stony	Dense tropical evergreen
Lengpui	Gentle slope	Warm	Clayey	Dense mixed bamboo
Mualkhang	Steep slope	Moderate warm and dry	Red, clayey	Moderate—thick tropical evergreen
Nausel	Steep slope	Moderate warm	Clayey	Evergreen, open scrub
Old Tisopi	Steep slope	Moderate warm	Red	Evergreen
Pamchung	Steep slope	Moderate warm	Clayey	Tropical evergreen, moderately dense mixed bamboo
Rawlbuk	Steep slope	Moderate	Stony	Evergreen, moderately thick
Saihapui K	Plain	Warm	Gravel/ Clayey	Evergreen, mixed with Bamboo
Thlengang	Steep slope	Moderate	Loamy soil	Thick tropical evergreen
Tualcheng	Steep slope	Cold	Clayey	Dense tropical evergreen

Source: Field survey, 2018.

climatic conditions remain ideal for the entire year between 800 m and 1,400 m. Altitude, cloudiness and rain play a greater role in maintaining a climate conducive. Soils of the villages are characterized by clayey, red, stony, swampy, gravel, loamy and mixed two soils. Most of the soils are infertile due to enormous soil erosion occurring mainly during the monsoon season. There are a few pockets such as flood plains and valley fills where soil fertility is high. The soil type is alluvial. Mizoram has rich floral diversity—ranging from mixed bamboo forests to tropical, subtropical, temperate mountainous and open scrub. The forests are the allied options for rural livelihoods.

Climate and Rural Livelihood

Climate is one of the natural capital/assets in Mizoram. It has a prominent role in agriculture and tourism development. Due to suitable climatic conditions, several crop cultivars/races are grown in Mizoram. Climatic conditions are also quite suitable for tourism development. The annual average temperature is about 22.5°C with a maximum of 32°C and a minimum 15°C temperature. The rainfall data for the last 32 years shows that the state receives high rainfall during the eight months of the year from March to October with 2,400 mm annual average rainfall. Crops are rain-fed and grown during this period. The highest rain occurs in July and August. As noticed more than 200 mm of rainfall decreased between 1986 and 2017 (32 years). The R^2 value was 0.027. However, the variation in rainfall was high during the period, which was 1,100 mm. The temperature is very feasible with 22.5°C annual mean value (Figure 1). The temperature variation was noted at about 5°C. The R^2 value was 0.070. With slight changes in climatic conditions, crop productivity was noted to decrease. Because of the fresh air, dense forests and pure water, the environmental sustainability index in Mizoram is 80%–100%, which is quite healthy. It can attract tourists and can enhance rural livelihoods. These advantages have not been explored so far.

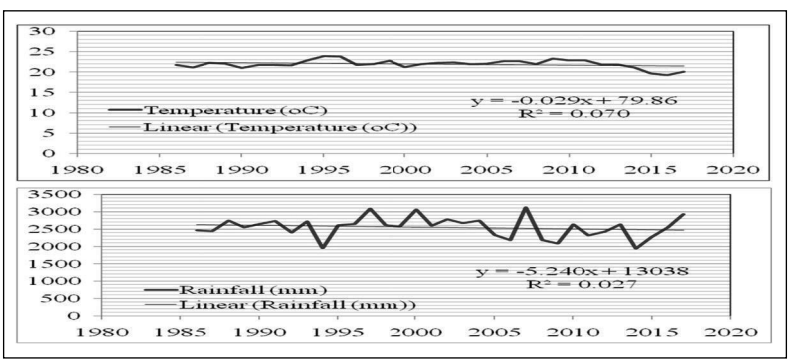

Figure 1. A Regression of Temperature and Rainfall Showing Trends during the Last 32 Years.

Source: The author.

Forest Resources and Rural Livelihoods

Out of its total area of 21,081 km^2, Mizoram possesses about 86% forest area (FSI, 2019). It has a rich biodiversity, which varies from tropical wet to subtropical wet, temperate montane and bamboo forests. Mizoram has 400 ethnomedicinal plant species, of which, 230 species have medicinal value. Similarly, there are 27 main species of bamboo (FSI, 2019). The forest resources are the major livelihood options in rural areas of Mizoram. The marginal farmers collect fuel-wood, fodder and food for running their livelihood. Agriculture in Mizoram is characterized by shifting cultivation, which is practised in arable plots of forest areas. Bamboo handicrafts, bamboo shoots and several green leaves support rural livelihoods.

Forests are abundant while agricultural land is quite less in these villages (Table 3). The mean value of agricultural land was 71.19 ha while the mean forest land was 272 ha in the selected villages. In terms of the per capita agricultural land, it was 0.26 ha (mean value). The mean per capita forestland was 2.15 ha. It shows that the per capita agricultural land was significantly less than the per capita forest land. However, both figures are higher than the national average. Mizoram has rich and valuable forests, whereas their use is subsistence in nature in rural areas. One of the reasons is the remoteness of the forest areas. The valuable products from the forests are unused and get destroyed naturally. If the forest products are sustainably used, the livelihood of rural people can be enhanced.

Figure 2 presents the figures on forest resources and their use patterns in the selected villages. Of the total forest area, 50% is comprised of bamboo forests. Bamboo has 27 species in Mizoram. Bamboo forests are found mainly below 800 m. These forests are highly vulnerable to forest fires. The *Jhumias* burn bamboo forests for converting them into *Jhumlands*. In the rural areas, the marginal farmers make handicrafts of bamboo. The forest department of the Mizoram government has started planting teak forests in valley regions. These are economically viable forests but these are highly vulnerable to climate change.

Figure 3 shows a map of forest and agricultural land use in Mizoram. The highest area of forest land use is under bamboo forests followed by open and dense forests. The agricultural land is significantly less. Forest is one of the important natural capitals upon which, the livelihood of the rural people is dependent. Mizoram has a dense drainage network. Most of the rivers are perennial but, during the winter, the volume of water remains low. The rivers flow in three directions—north, south and west.

Table 3. Agricultural and Forestland (n = 16).

Variables	Mean	Std. Deviation
Population	381.8	468.6
Agricultural land	71.19	35.7
Per capita agricultural land	0.26	0.13
Forestland	272	242.8
Per capita forest land	2.15	1.63

Source: The author.

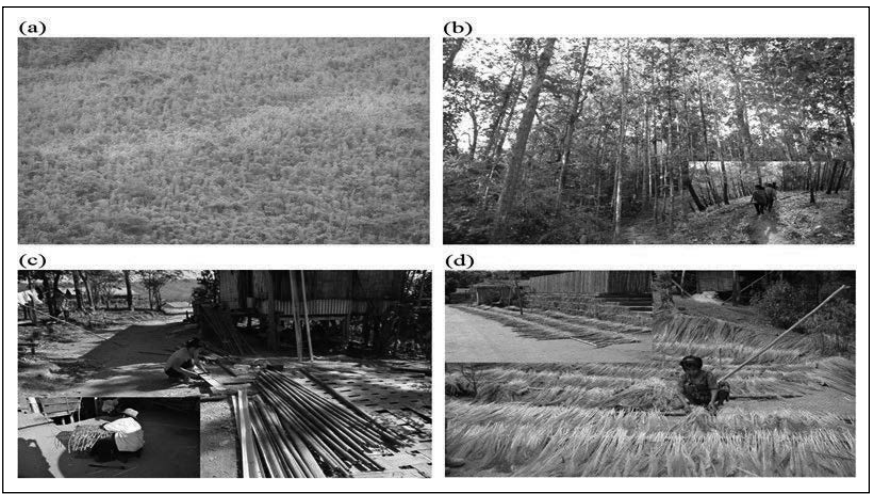

Figure 2. (a) Extensive Bamboo Forests, (b) Teak Forests, (c) Rural People Enhancing Livelihood through Making Bamboo Products and (d) Brooms.

Source: The author.

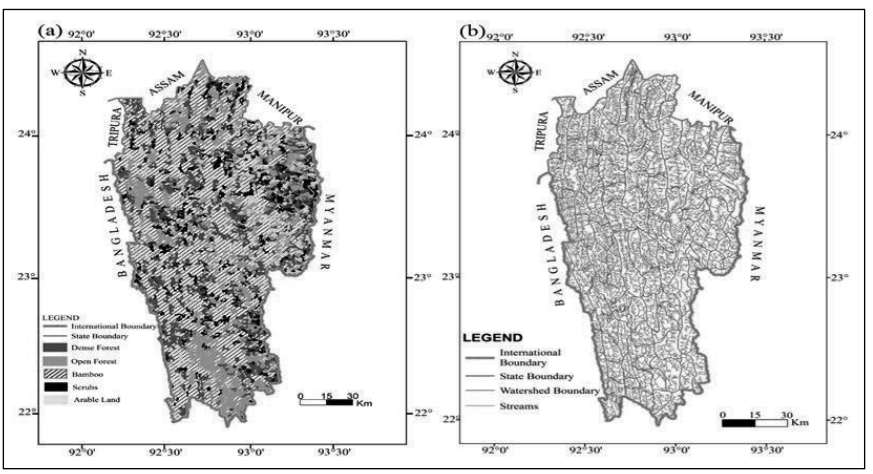

Figure 3. (a) Forest and Agricultural Land Use and (b) Micro-Drainage Basin.

Source: Sati (2020).

Water Resource Potential and Rural Livelihood

Mizoram has plenty of water resources in the form of abundant rainfall, perennial rivers, lakes and natural springs (Figure 4). A total of 21 rivers and their tributaries make up about 1,700 km in length within the state (Gurumayum & Choudhury, 2009; MIRSAC, 2018). Canals are constructed about 1,400 km in length. The total area under water bodies is 20 km^2, which is 0.1% of the total geographical

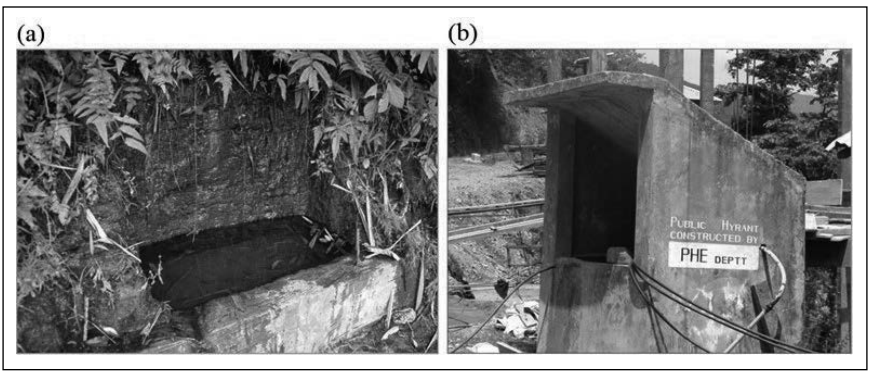

Figure 4. (a) Natural Spring, Traditional Water Source. (b) Water Supply by Government Water Agency.

Source: The author.

area of the state. Mizoram has a 4,500 MW hydroelectricity generation potential, of which, 29.35 MW of electricity is generated so far, which is 0.7% of the total potential (Department of Irrigation, 2018). Despite the abundance of water resources, Mizoram faces water scarcity during the off-season. The settlements both rural and urban are situated mainly on the hilltop and the perennial rivers flow through the valleys (SOER, 2016). The natural springs are recharged during the monsoon season, whereas they dry up during the off-season leading to acute water scarcity/shortage. Sustainable use of available water may provide water for irrigation, drinking and construction of hydropower projects.

Potential of Agricultural Capital in Livelihood Sustainability

Practising agriculture in Mizoram is one of the important physical capital. More than 50% of people are engaged in practising agriculture. Meanwhile, the agricultural land is very less, only about 5.5% of the total geographical area, and the output from the arable land is nominal, not sufficient to meet even the two times food need. Shifting cultivation is carried out mainly in Jhumlands (shifting plots), which are sloppy and undulating. Therefore, rural people are facing food scarcity. The state has rich agro-climate and agro-biodiversity. It can grow a variety of crop cultivars/races along the altitudinal gradient (200 m to 2,000 m altitude) and from tropical to subtropical and temperate climates. If the Jhumlands are allotted permanently to the marginal farmers and crops are grown according to the agro-climate, the livelihood of the marginal farmers can be enhanced. Agriculture is rainfed, mainly grown during the rainy season with a low output. Rice, which is a staple food, production can be increased through systematic rice intensification. It has been noticed that the production of rice under systematic rice intensification in the plain region is quite higher (just double) than the rice grows in shifting cultivation. Therefore, the abundant water potential of the state

can be used for intensive irrigation in the valley plains and systematic rice intensification can be carried out in more arable land. This will lead to sufficient rice production and food security in Mizoram.

Area, Production and Yield of Principal Crops

The area, production and productivity of principal crops in two times—2000 and 2018 are presented here. Changes in the area, production and productivity are also presented. A correlation between altitude, accessibility and productivity are analysed. The production and consumption of rice, major sources of income, and income at the household level have been assessed. Agro-biodiversity is high in the study villages. There are several crop cultivars/races grown, mainly rice, fruits and vegetables. Data on the area, production and productivity of the principal crops at two different times were gathered. Rice, a staple food, has the highest area, production and productivity, multifold than the other crops (Table 4). Among fruits, bananas grow largely. The state of Mizoram is one of the largest producers of bananas in India. Orange, lemon, mango and pineapple are the other major fruits grown in these villages. Their production and productivity are significant. Between 2000 and 2018, the area, production and productivity of all crops increased. However, due to inaccessibility to market and a lack of adequate storage facilities, some of the products remained underused largely during their growing season.

Rice is mainly grown in the river valleys and flood plains as WRC (irrigated) and along the hilly slopes under shifting cultivation, which is rain-fed. Rice under rain-fed is grown once a year. Its productivity is high in comparison to other crops in the study villages. However, the production is not sufficient to feed the large rural population there. The area and production of oranges are increasing (Figure 5). The state government has introduced high-yield variety orange cultivars. The economic viability and environmental suitability of the orange are high in the ecologically fragile landscape of Mizoram.

Table 4. Area (ha), Production (kg) and Productivity (kg/ha) of Principal Crops.

	2000			2018		
Crops	Area	Production	Productivity	Area	Production	Productivity
Pine apple	4.5	266.66	59.26	30.04	3,739	124
Mango	5.5	65.02	11.82	51.52	910	17.67
Lemon	6	25.01	4.17	560	428	0.76
Orange	7	23	3.29	99.5	12,734	127
Banana	26.7	474.33	17.77	101	9,466	93.22
Rice	170.5	288,861	1694	273	372,256	1361
Total	220.2	289,715	1790.31	1115.06	399,533	1723.65

Source: The author.

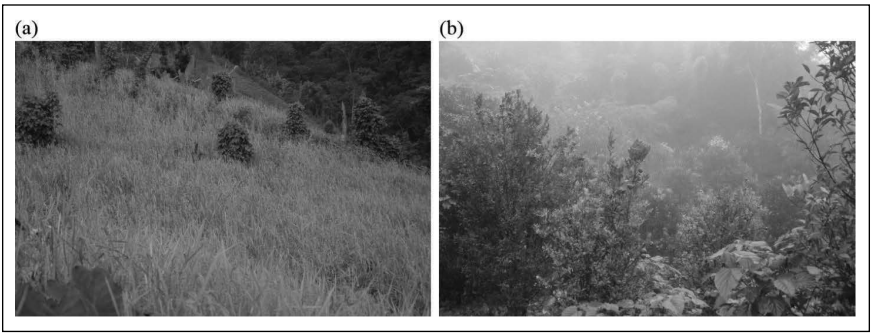

Figure 5. (a) Rice Grows in a Traditional *Jhumland* and (b) Orange Production is Increasing in the Study Villages.

Source: The author.

Table 5. Change in Area, Production and Yield of Principal Crops (2000–18).

Crops	Area (ha)	Production (kg)	Productivity (kg/ha)
Pineapple	25.54	3472.34	64.74
Mango	46.02	844.98	5.85
Lemon	554	402.99	–3.41
Orange	92.5	12,711	123.71
Banana	74.3	8991.67	75.45
Rice	102.5	83,395	–333
Total	1113.8	217,127	–750

Source: The author.

Change in Area, Production and Productivity of Principal Crops

The changes in the area, production and productivity of the principal crops are presented in Table 5. The area of all crops is increasing, with the highest for lemon, rice and orange. Similarly, the production is increasing with the highest of rice, orange, bananas and pineapple. It has been noticed that the productivity of rice and lemon has decreased while the productivity of oranges is the highest. Bananas, oranges and pineapples are the major cash crops, which have a large potential to grow and enhance rural livelihoods.

Productivity of Crops

The productivity of crops was presented in Table 6. The mean value of productivity for rice is the highest (968.26 kg/ha). The mean value of productivity of banana, pineapple and orange is also high. However, these crops are grown in a few villages. Rural livelihood can be enhanced by growing these crops in all villages.

Table 6. Productivity (kg/ha) of Principal Crops.

Crops	Minimum	Maximum	Mean	Std. Deviation
Rice (*n* = 16 villages)	408	2,000	968.26	452.66
Mango (*n* = 7 villages)	2	44	29.52	14.81
Lemon (*n* = 7 villages)	1	333	98.48	116.28
Pine apple (*n* = 8 villages)	20	278	162.97	104.93
Orange (*n* = 8 villages)	1	558	161.27	184.15
Banana (*n* = 8 villages)	13	668	201.57	228.68

Source: The author.

Altitude and Rice Productivity

A correlation between altitude and rice productivity is presented in Figure 6. It has been noticed that the rice productivity has increased slightly along with increasing altitude and the R^2 value was noticed at 0.037. It means that the agroecological conditions are better at high altitudes where many crop races can be grown.

The Accessibility of Farmlands and Rice Productivity (kg/ha)

The villages in rural areas of Mizoram are remotely located. Of the total 16 villages, the farmlands of 7 villages are accessible, and the rests of them are very inaccessible average of 30 km distance. Data on the accessibility of farmlands and productivity (kg/ha) were analysed. The productivity of rice varied between 500 and 1,200 kg/ha as per the accessibility of the farmlands. The overall correlation between accessibility and productivity shows that rice productivity was higher in the accessible farmlands (Figure 7).

Production and Consumption of Rice

Data on the production and consumption of rice were collected from the study villages (Table 7). The consumption of rice is almost three times higher than production. The farmers can store rice for a maximum of three months. To meet the rice demand, the central government provides rice at subsidized rates under the public distribution system.

Sources of Income and Households

The sources of income and households involved in different activities are presented in Table 8. The results show that the highest mean value of income was from government services, followed by income from a business, animal husbandry and crop sales. The lowest mean income was earned from the kitchen garden,

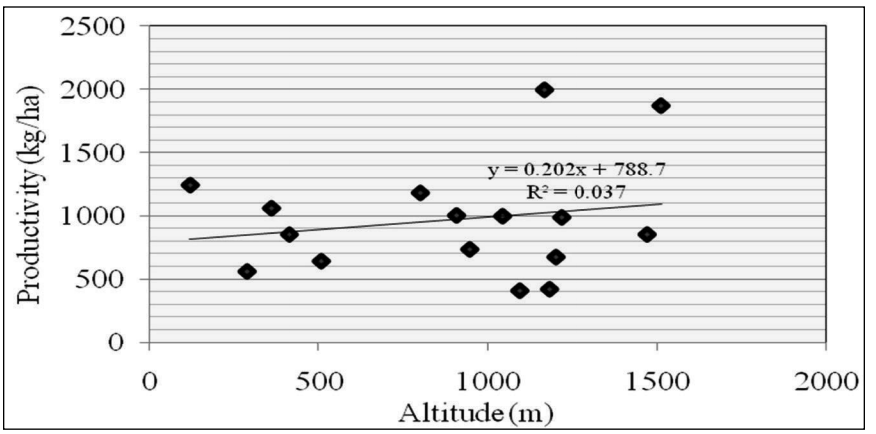

Figure 6. Productivity of Rice (kg/ha) in the Altitude.

Source: The author.

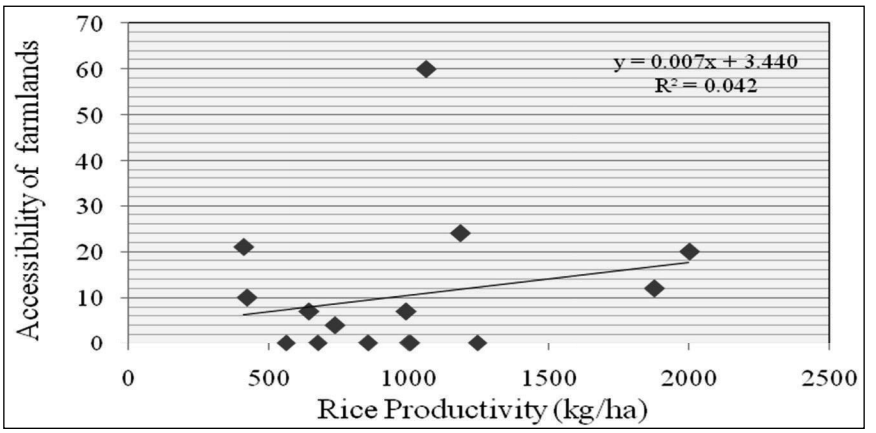

Figure 7. Accessibility of Farmlands and Rice Productivity.

Source: The author.

Table 7. Production and Consumption of Rice.

Variables (n = 16)	Minimum	Maximum	Mean	Std. Deviation
Rice production (kg)	210	206,250	23,266	49,841
Annual rice consumption (kg)	24,132	380,760	71,163*	86,030
Monthly rice consumption (kg)	2,011	31,730	5,930	7,169
Secure months	0	22	3.76	5.64

Source: The author.

Note: *The rice demand is met by the subsidized public distribution system.

Table 8. Source of Income and Households Involved.

	Source of Income		Households Involved	
Variables	Mean (Rs.)	Std. Deviation	Mean (HHs)	Std. Deviation
Shifting cultivation (*n* = 16)	2,187	534	87.56	61.11
Lumbering (*n* = 9)	3,011	2,832	2.44	2.29
Driving (*n* = 16)	13,350	36,042	6.00	14.28
Daily wages (*n* = 16)	142,350	200,312	73.56	111.38
Kitchen garden (*n* = 16)	2,103	1,833	1.2	1.1
Crop sale (*n* = 1)	39,000	00	13.00	00
Small trading (*n* = 16)	13,500	24,630	5.00	6.63
Animal sale (*n* = 1)	5,000	00	5.00	00
Business (*n* = 5)	81,400	156,018	20.60	38.86
Church services (*n* = 3)	10,333	11,930	3.67	3.79
Pension (*n* = 16)	13,125	36,116	1.81	4.55
Government services (*n* = 16)	402,812	822,681	17.75	30.84
Animal husbandry (*n* = 16)	49,318	61,725	60.56	73.18
Other (*n* = 16)	35,437	88,588	18.00	44.19

Source: The author.

shifting cultivation, lumbering and animal sale. Meanwhile, the highest number of people is involved in practising shifting cultivation, whereas a few people are involved in the service sector. This is also a reason for declining agricultural practices in the study villages.

Income at Household Level

The monthly income at the household level was gathered and analysed (Figure 8). It has been noted from the data that the monthly income is less than Rs. 5,000 for about 36% of the households. A few households have an income of more than Rs. 25,000. As mentioned in the above paragraphs, a large number of people are engaged in practising shifting cultivation with low output; therefore, the income of the household is very small. A few people are employed in the service sector and their monthly income is comparatively high. This is one of the reasons that about 33% of people are living below the poverty line.

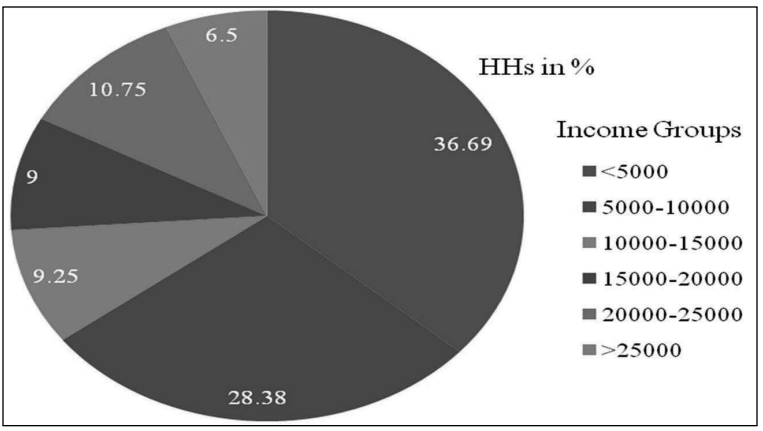

Figure 8. Household-Level Income under Different Income Groups.

Source: The author.

Conclusions

Mizoram has abundant natural capital in the form of a feasible climate, panoramic landscape, rich forest diversity, ample water and suitable agro-climate. However, these natural capitals are not used adequately. The remote rural areas lack infrastructural facilities to exploit the resources there. Development of infrastructural facilities and sustainable use of all the natural capital can enhance livelihood options and can attain food security. Due to its rich biodiversity and a large area under tropical, subtropical and temperate montane forests, the Forest Department of Mizoram has declared protected forest areas as national parks, wildlife sanctuaries and conservation reserves. Apart from these capitals, Mizoram has a rich culture and cultural heritage. It has organic food products and traditional beverages. The climatic conditions are quite suitable for sustainable tourism development mainly nature and leisure tourism, village tourism, and national parks and wildlife tourism. Harnessing these natural and cultural capitals along with the involvement of the local people can be ensured in the process of tourism development, which will augment employment and generate income for rural people.

Due to the remoteness of forest areas and lacking infrastructure facilities, the forest products remain largely unused. The local people use forest products at the subsistence level only. The potential of forests for livelihood sustainability is important. The bamboo products can be used to make furniture, and arts and crafts. These can also be sold out in the other states. Small-scale village-based forest industries can be established. Sustainable use of timber and non-timber forest products can enhance the livelihood of the local people. Mizoram has plenty of water resources. It is one of the states of India where rainfall occurs often and where many perennial streams flow. Meanwhile, for about four months of the

year, the rural areas of Mizoram face water scarcity. The rainwater can be harvested sustainably if the required technology is adopted. Rainwater can be stored by constructing ponds, checking dams and field buds. The construction of micro-hydropower projects is feasible for the landscape, which will increase the energy capacity of rural areas. Watershed management is vital to the optimum use of forest, water and other physical capital. The conservation and rejuvenation of natural springs in rural areas will reduce water scarcity. In the urban centres, roof water harvesting can be practised. All these measures will provide ample water supply to the rural areas and will solve the water scarcity problems and enhance rural livelihoods.

Agriculture is the main occupation and the major source of livelihood in Mizoram. The production and productivity of crops are small. Due to less arable land, crop production is inadequate. System rice intensification in the flood plains and valley fills may increase the production and productivity of rice. Among the fruits, orange, mango, pineapple and bananas are promising crops. Therefore, these can be grown in all villages. Many crops do not find a market and are thus consumed in producing households. The state government can provide market facilities to fruit and vegetable growers, which will support food security for marginal farmers. Fruit processing centres can be established in each village. Juice of orange and pineapple and chips of banana can be sold in the regional market during the off-season. The production of lemon can be increased and value addition through making lemon juice and providing an appropriate market will surely enhance rural livelihoods. The agro-climate of Mizoram is quite suitable for growing many crops and crop races—food grains, vegetables and fruits. The sustainable use of agro-climate for growing crop races/cultivars will increase the income of marginal farmers and the economy of the state.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding

The author received no financial support for the research, authorship and/or publication of this article.

References

Aase, T. H., Chaudhary, R. P., & Vetaas, O. R. (2009). Farming flexibility and food security under climatic uncertainty: Manang, Nepal Himalaya. *AREA: Royal Geographical Society (with the Institute of British Geographers)*, *42*(2), 228–238. https://doi.org/10.1111/j.1475-4762.2009.00911.x

Acharya, S. S. (2006). *Sustainable agriculture and rural livelihoods* (Monograph No. 6, ICSSR Occasional Monograph Series). Indian Council of Social Science Research.

Adam, Y., Pretzsch, J., & Pattenella, D. (2013). Contribution of non-timber forest products livelihoods strategies to rural development in drylands of Sudan: Potentials and failures. *Agricultural System*, *117*, 90–97. https://doi.org/10.1016/j.agsy.2012.12.008

Amir-ud-Din, R., Usman, M., Abbas, F., & Javed, S. A. (2017). Human versus physical capital: Issues of accumulation, interaction and endogeneity. *Economic Change and Restructuring*, *52*, 351–382. https://doi.org/10.1007/s10644-017-9225-2

CBD. (2021). Twelfth Conference of the Parties to the Convention on Biological Diversity (CBD). Retrieved April 23, 2022, from https://www.cbd.int/business/projects/natcap.shtml

Census of India (COI). (2011). Census of India. Registrar General, New Delhi. https://censusindia.gov.in/census.website/

Cline, W. R. (2008). Global warming and agriculture. *Finance and Development*, *45*(1), 23–27.

Daily, G. C., Zhiyun, O., Hua, Z., Shuzhuo, L., Yukuan, W., Feldman, M., Kareiva, P., Polasky, S., & Ruckelshaus, M. (2013). Securing natural capital and human well-being: Innovation and impact in China. *Acta Ecologica Sinica*, *33*(3), 677–685.

Department of Irrigation. (2018). *Water potential in Mizoram*. Government of Mizoram Publications.

Edward, B. B. (2019). The concept of natural capital. *Oxford Review of Economic Policy*, *35*(1), 14–36. https://doi.org/10.1093/oxrep/gry028

FAO. (2017). *Improving livelihood and economic sustainability in Mizoram, India*. Food and Agriculture Organization (FAO) of the United Nations. https://www.fao.org/documents/card/en/c/CA4939EN/

FSI. (2019). *Forest Survey of India, Annual Report*.

Gong, L., Li, H., & Wang, D. (2012). Health investment, physical capital accumulation, and economic growth. *China Economic Review*, *23*(4), 1104–1119. https://doi.org/10.1016/j.chieco.2012.07.002

Gurumayum, S. D., & Choudhury, M. (2009). Fishing methods in the rivers of Northeast India. *Indian Journal of Traditional Knowledge*, *8*(2), 237–241.

Hanjra, M. A., Ferede, T., & Gutta, D. G. (2017). Reducing poverty in sub-Saharan Africa through investments in water and other priorities. *Agricultural Water Management*, *96*(7), 1062–1070.

Huddleston, B., Ataman, E., & d'Ostlanl, L. F. (2003). *Towards a GIS-based analysis of mountain environments and populations* (Working Paper No. 10). Food and Agricultural Organization. https://www.fao.org/3/y4558e/y4558e00.pdf

ICIMOD. (1996). Background note for a regional meeting of experts on the development of micro-enterprises in the mountain area. Unpublished Text (25–26 July).

IPCC. (2007). Climate change 2007: Impacts, adaption, and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Retrieved October 24, 2015, from http://www.ipcc.ch/ipccreports/ar4-wg2.htm

Leblhuber, S. K., & Vanlalhruaia, H. (2012). Jhum cultivation versus the new land use policy: Agrarian change and transformation in Mizoram. In D. Münster, U. Munster, & S. Dorondel (Eds.), *Fields and forests: Ethnographic perspectives on environmental globalization, RCC perspectives* (pp. 83–89). https://www.environmentandsociety.org/perspectives/2012/5/article/jhum-cultivation-versus-new-land-use-policy-agrarian-change-an

Maithani, B. P. (2005). *Shifting cultivation in North-East India: Policy issues and options*. Mittal Publications.

MIRSAC. (2018). *Mizoram Remote Sensing Application Centre*. Mizoram Remote Sensing Society.

Natural Capital Committee. (2015). *The state of natural capital: Protecting and improving natural capital for prosperity and wellbeing*. Natural Capital Committee. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/516725/ncc-state-natural-capital-third-report.pdf

NITI Aayog. (2018). NITI Aayog Report of India.

Ramakrishnan, P. S. (1992). *Shifting agriculture and sustainable development: An interdisciplinary study from North-eastern India*. UNESCO. https://digitallibrary.un.org/record/137892?ln=en

Raman, T. R. S. (2001). Effect of slash-and-burn shifting cultivation on rainforest birds in Mizoram, Northeast India. *Conservation Biology*, *15*(3), 685–698. https://doi.org/10.1046/j.1523-1739.2001.015003685.x

Sati, V. P. (2020). New land use policy and its contribution in sustainable permanent agriculture in Mizoram. *Indian Journal of Hill Faming*, Special Issue, 113–120.

Sati, V. P., & Vangchhia, L. (2016). Nutritional status and infant mortality rate in Saiha District, Mizoram, India. *Current Science*, *110*(12), 2280–2285.

Sati, V. P., & Vangchhia, L. (2018). Food security status in rural areas of Mizoram, Northeast India. *Journal of Mountain Science*, *14*(4), 795–805. https://doi.org/10.1007/s11629-016-4092-2

SOER. (2016). *State of Environment Report*. Department of Environment, Forest, and Climate Change, Government of Mizoram.

State Statistical Handbook. (2017). *Statistical Hand Book*. Department of Statistics, Government of Mizoram.

Sun, J., & Dong, Y. (2007). Human capital, physical capital and economic growth: An empirical study based on Chinese data. *Journal of Shanxi University of Finance and Economics*, *29*(4), 37–43. http://www.cqvip.com/qk/96461a/200704/24410566.html

Tiwari, P. C., & Joshi, B. (2011). *Urban growth and food security in Himalaya* [International Working Paper Series]. Urbanization and Global Environmental Change (UGEC) Viewpoint, International Human Dimension Programme (IHDP).

Tiwari, P. C., & Joshi, B. (2012). Natural and socio-economic factors affecting food security in the Himalayas. *Food Security*, *4*(4), 195–207. https://doi.org/10.1007/s12571-012-0178-z

Tscharntke, T., Clough, Y., Wanger, T. C., Jackson, L., Motzke, I., Perfecto, I., Vandermeer, J., & Whitbread, A. (2012). Global food security, biodiversity conservation, and the future of agricultural intensification. *Biological Conservation*, *151*(1), 53–59. https://doi.org/10.1016/j.biocon.2012.01.068

UNDP. (2006). *Human development report 2006. Beyond scarcity: Power, poverty, and the global water crisis*. United Nations Development Programme. https://hdr.undp.org/content/human-development-report-2006

Article

Reduction in Firewood Consumption due to Implementation of Improved Cookstoves in Melghat Tiger Reserve, India

Asia-Pacific Journal of Rural Development
32(1) 26–36, 2022

DOI: 10.1177/10185291221114950
journals.sagepub.com/home/jrd
SAGE

Jayant Kulkarni[1], Prachi Mehta[1], Anuja Vartak[1], Dipankar Ghose[2] and M. Sreenivas Reddy[3]

Abstract

According to the 2001 Census of India, around 82% of the rural population of India depends entirely on biomass and uses primitive cookstoves for cooking. The smoke released due to incomplete combustion causes several chronic respiratory disorders among women responsible for cooking. Despite these adverse effects, people continue to use traditional cookstoves due to their simplicity. Firewood consumption is also responsible for the degradation of forests and the emission of CO_2, which is a major greenhouse gas. A project was implemented by Wildlife Research and Conservation Society in 12 villages in Melghat Tiger Reserve to introduce improved cook stoves in 1,098 households for reducing firewood consumption and smoke emission. This study estimated that the improved cookstoves (ICS) had reduced the average per capita firewood consumption by 0.61 kg/day (25%) and resulted in the conservation of 1,171 tons of firewood annually. A decrease of 1,953 tons of CO_2 emissions due to the installation of ICS has been estimated. Installation of ICS reduced the time taken to cook a meal by an average of 40 minutes and reduced smoke production, thereby contributing to the health of the users.

Keywords

Improved cookstoves, CO_2 emission, firewood consumption, Melghat Tiger Reserve, smoke production, cooking time saving

[1] Wildlife Research and Conservation Society, Pune, Maharashtra, India
[2] Landscape and Species Conservation, WWF-India, New Delhi, India
[3] Melghat Tiger Reserve, Amravati, Maharashtra, India

Corresponding author:
Jayant Kulkarni, Wildlife Research and Conservation Society, 1A, Shriyog, 127/3, Sus Road, Pashan, Pune, Maharashtra 411021, India.
E-mail: jayantkulkarni@wrcsindia.org

Introduction

Biomass and coal are used as domestic fuel by around three billion people worldwide representing approximately 13% of the total energy consumption (Amegah & Jaakkola, 2016; Bonjour et al., 2013; Khandelwal et al., 2016; Popp et al., 2021). In developing nations, most rural households use firewood for their domestic cooking, whereas urban households depend mainly on liquid petroleum gas (LPG) or electric cooktops for cooking (Arnold et al., 2006; Win et al., 2018). Nearly 86.5% of the rural population depends primarily on solid biomass for cooking, whereas in the case of the urban population it is only 26.2% (Chandramouli, 2011), indicating a drastic difference in domestic fuel consumption patterns. People residing in remote forest areas depend predominantly on firewood from the forest for their day-to-day activities such as domestic cooking and heating water. Most households use primitive cookstoves made of clay for cooking and heating. These stoves have an efficiency of 5% to 15%. The low efficiency of traditional cookstoves increases firewood consumption and exerts more pressure on natural resources. Firewood combustion in these cookstoves is incomplete, releasing substantial amounts of black carbon (soot) and carbon-based greenhouse gases, which cause chronic illnesses, like asthma and other lung disorders, among women responsible for domestic cooking (Khandelwal et al., 2016). Approximately four million people die every year across the globe because of indoor air pollution (WHO, 2014). Despite this, people continue to use traditional firewood cook stoves because firewood is free and easily accessible.

To promote clean energy use for domestic purposes, the Government of India has introduced programmes such as the Pradhan Mantri Ujjwala Yojana for promoting the installation and use of LPG units (Patnaik et al., 2019). Subsidised LPG units are also distributed under the Shyamaprasad Mukherjee Jan Van Yojana of the Maharashtra Forest Department (Government of Maharashtra, 2012). Interestingly, the uptake of LPG units is a small percentage of the population in the region (Patnaik et al., 2019). Moreover, through a pilot study carried out by the first author in the project area in 2017, it was observed that villagers who installed LPG in their houses, continued to use firewood for some of their energy requirements. Thus, there is a need for improving the efficiency of firewood cook stoves.

Several researchers have experimented with improving the efficiency of cookstoves and reported that it is possible to get the masses to accept it (Food and Agriculture Organization, 2010; Jeuland & Pattanayak, 2012; Pattanayak et al., 2019; Thakur et al., 2019). In India, improved cook stoves (ICS), which improve the efficiency of cooking, are an often-used idea to reduce firewood consumption, lower the smoke released from the kitchen and thereby help women improve their health and conserve native trees of the area (Pande et al., 2018). It has been a common perception that households below the poverty line would prefer using ICS if they are made available at low costs, to reduce indoor air pollution, but the progress in adopting ICS on large scale has been exceptionally slow (Bailis et al., 2009; Jeuland & Pattanayak, 2012). The efforts to design and distribute ICS began

in India in the 1930s. In India, after independence, the effort to introduce efficient cook stoves became a part of development projects initiated by various government and non-governmental organisations. Today, in the rural parts of India, the inability to create effective designs has made it difficult for people to cook certain culturally important types of foods and has resulted in a reluctance to use ICS (Adler, 2010; Bhojvaid et al., 2014; Khandelwal et al., 2016; Pande et al., 2018).

Firewood consumption exerts considerable biotic degrading pressure on the forests and is an important factor in degrading tiger habitats (De & *Chauhan,* 2015). Therefore, the need for implementing ICS in the villages of Melghat Tiger Reserve (MTR) was identified as an important requirement to reduce pressure on the tiger habitat. Moreover, through a pilot survey, it was observed that villagers who installed LPG in their houses continued to use firewood for some of their domestic heating requirements. To reduce the impact of domestic firewood consumption on the forests of MTR, we implemented a project for the distribution of ICS in 12 villages in MTR in 2018 and 2019. A study was carried out to assess the benefits of ICS in reducing firewood consumption and other benefits.

Description of Study Area

MTR (21°25′40″, 77°6′20″), in Amravati District, is located on the northern boundary of Maharashtra state. Located in Satpura Hill Ranges, the terrain of Melghat is marked by hilly and rugged terrain, while some parts towards the northern boundary have fairly plain terrain. In 1972, it was among the first nine tiger reserves to be declared in the country. The total extent of the Melghat forest is 2,768 km^2. The main indigenous communities in Melghat are Korku, Gawli and Gond. Most of them practice sustenance agriculture.

The region has three district seasons: the monsoons from the middle of June to September, the winter season from October to February, and the summer season from March to the middle of June. May is the hottest month when the temperature can reach up to 48°C while in winters the temperature can dip to 3°C. Forests are mainly dry deciduous forests classified as Subgroup 5A Southern Tropical Dry Deciduous forests. Out of the total forest area, almost 75% of the forest is teak dominated, while 25% of the area is mixed, composed of species like *Anogeissus latifolia, Lannea coromandelica, Butea monosperma, Haldina cordifolia, Mitragyna parviflora* and *Garuga pinnata*. Bamboo is widely distributed in Melghat's forests. *Lantana camara, Wrightia tinctoria, Helicteres isora, Zizyphus rugosa* represent the undergrowth in the forests (Tyagi, 2014). MTR has a rich biodiversity. Among the carnivores, Tiger *Panthera tigris*, Leopard *Panthera pardus*, Wild dog *Cuon alpinus,* Sloth bear *Melursus ursinus*, Striped hyaena *Hyaena hyaena* are present in these forests. Herbivores such as Nilgai *Boselaphus tragocamelus*, Sambar *Rusa unicolor*, Chital *Axis axis,* Gaur *Bos gaurus*, Muntjac *Muntiacus muntjac and* Four-horned antelope *Tetracerus quadricornis* are found in the tiger reserve.

Improved Cookstove

A traditional clay cookstove has a horseshoe-shaped construction with an opening wide enough for inserting the wood required for burning. This same design has continued for ages and has the advantage that it can be easily made from local materials by the homemakers (Plate 1). However, it has some shortcomings that reduce its efficiency. Due to congestion of the firewood sticks, causing the poor supply of air, there is incomplete combustion of firewood, reducing the energy efficiency of the cook stove. It results in a smoky flame, which increases the chance of respiratory disorders (Khandelwal et al., 2016).

ICS design installed by WRCS addresses some of the shortcomings in the traditional cook stove. The most important principle of the ICS is grating. A cast-iron grating of size 20 × 20 cm is installed at the bottom of the ICS and a channel is created beneath the grating to allow airflow into the cookstove. This is done by digging a tunnel in the floor below the ICS or by installing the ICS on a raised brick platform, leaving a channel between the bricks for airflow. The grating allows ash to fall down so that it does not smother the flame. The unobstructed supply of air allows the firewood to burn completely and increases the efficiency of the cookstove (Wilson et al., 2016).

At the beginning of the project, a clay cookstove model was implemented using a design provided by Samuchit Envirotech. However, the community members preferred an open construction that allows them to roast their traditional unleavened jowar and wheat bread on an open flame. Second, clay cookstoves were often damaged due to water spilling on them. In such cases, the beneficiaries just returned to their traditional cookstoves. Third, during the process of constructing a new house under a government scheme, the ICS was often left behind in the old house. Keeping the above constraints in mind, we designed a cement ICS, in which the grating was built into the stove. This made the ICS portable and durable. An open model was designed, as preferred by the community. This new design of the cement cookstove was more acceptable to the community (Plate 2). We distributed 1,098 ICS in 12 villages that lie mainly in the buffer zone of MTR.

Plate 1. Traditional Cook Stove Made From Clay.

Source: The author.

Plate 2. Improved Cement Cook Stove Designed by the First Author.

Source: The author.

Survey Methodology

Assessment of firewood consumption was carried out from March 2018 to May 2018, and from March 2019 to June 2019. Measurement of the firewood consumption of each surveyed household was carried out daily for three days before the installation of ICS (Tables 2 and 3). A quantity of firewood was weighed and provided to the beneficiary household at the beginning of the day. The quantity remaining was again weighed at the end of the day, and the quantity used was calculated as the difference between the initial and final quantities. This procedure was repeated again for three days, after the installation of the ICS. Simultaneously, a structured interview was carried out with the beneficiaries to record their household data, understand their cooking habits, and their perception regarding the benefits of using ICS. Additional variables in the questionnaire were the names of dominant tree species used as firewood, the kind of food cooked, and the number of times food was cooked per day. Generally, the woman homemaker responsible for household cooking was interviewed, since she had a good understanding of the cooking process and was best able to assess the benefits accrued from the ICS. Totally, 215 households were surveyed for firewood consumption.

The surveyed households are divided into the following three sizes: small (1–4 members), medium (5–8 members) and large (9–12 members) following Shastri et al. (2002). For each household, the saving in the quantity of firewood used per day is calculated as the decrease in firewood consumption after the installation of ICS. The average saving of firewood consumption is calculated for each household size.

Results and Discussion

Most households used the cookstoves four times a day for boiling water, milk and tea, and for cooking meals, which included preparing the traditional jowar and wheat bread, curry and rice.

Traditionally, almost 100% of households use clay stoves, with firewood as the fuel. A small percentage of households used LPG, agro waste and cow dung as fuel. After installing the ICS, 100% of the households used ICS, but about 60% of them also continued to use clay stoves, and 8% continued to use LPG (Figure 1).

The tree species that are commonly used as firewood are *Tectona grandis, Aegle marmelos, Lagerstroemia parviflora, Anogeissus latifolia, Emblica officinalis, Wrightia tinctoria, Schleichera oleosa* and *Limonia acidissima*. Of these, the most commonly used species were *Anogeissus latifolia, Tectona grandis, Lagerstroemia parviflora* and *Aegle marmelos* (Figure 2).

The firewood species usage was governed partly by availability and partly by preference for particular species. The dominant species used as firewood are *A. latifolia* (26%), *T. grandis* (23%), *L. parviflora* (21%) and *A. marmelos* (16%). Of the 1,098 households to which cookstoves were distributed, 49.8% of the households were classified as small households, 45.6% as medium households

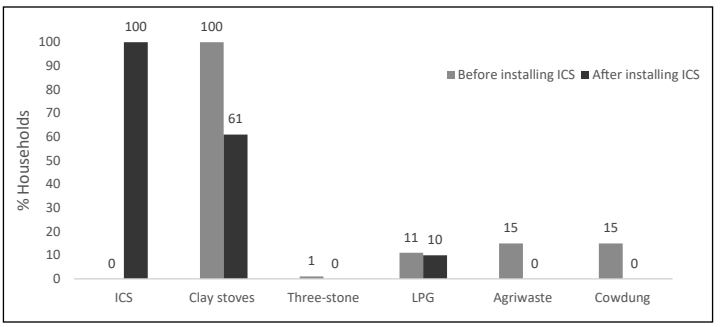

Figure 1. Usage Pattern of Various Stoves and Fuels Before and After Installation of ICS.

Source: The authors.

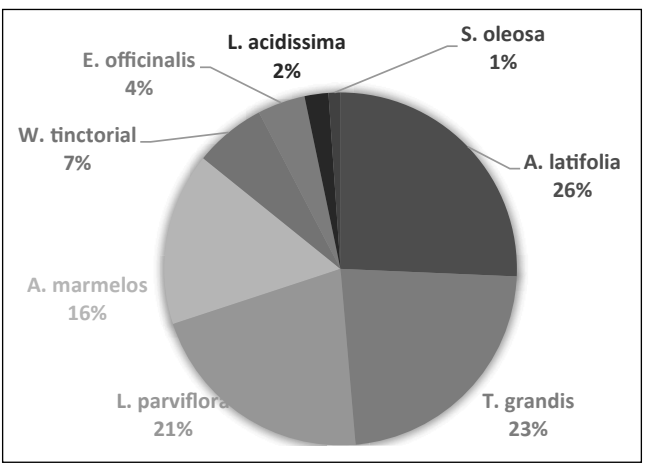

Figure 2. Dominant Tree Species Used as Firewood (%).

Source: The authors.

and 4.6% as large households (Table 1). There is a fairly large range in village size and the total number of households ranged in the village from 38 (Dhokda) to 330 (Golai). The coverage of households by ICS was partial, either because some house owners were absent when the ICS were distributed, or because they were not willing to accept the ICS. Overall, 65.7% of the households in the project villages received the ICS.

Among the 215 surveyed households, 56 were small households, 139 were medium households and 20 were large households. The per capita firewood consumption was highest in small households and least in large households. The absolute decrease in per capita firewood consumption was also highest in small households and least in large households. The percentage decrease in firewood consumption ranged from 23.8% in medium households to 30.8% in large households (Table 2).

Table 1. Distribution of ICS in Each Village According to Family Size.

	Distribution of ICS According to Family Size			
Village	Small	Medium	Large	Total
Bibamal	51	48	4	103
Chaurakund	92	83	0	175
Chilati	65	9	0	74
Dhokda	5	7	2	14
Golai	146	140	17	303
Raipur	64	60	3	127
Khokmar	11	42	9	62
Kuhi	26	20	0	46
Malur	46	44	4	94
Chopan	18	18	3	39
Tangda	17	17	5	39
Rangubeli	6	13	3	22
Total	547	501	50	1,098

Source: The authors.

Table 2. Estimates of Firewood Consumption by Family Size Before and After of ICS.

	Small		Medium		Large	
	Before	After	Before	After	Before	After
Number of households surveyed	56	56	139	139	20	20
Firewood used for cooking (kg/capita/day)	3.8 (±1.6)	2.8 (±1.1)	2.1 (±0.5)	1.6 (±0.5)	1.3 (±0.5)	0.9 (±0.5)
Firewood conserved per day (kg)	1 (±1.1)		0.5 (±0.4)		0.4 (±0.3)	
Decrease in firewood consumption (%)	26.3		23.8		30.8	

Source: The authors.

Based on the values of daily per capita firewood combustion before and after the installation of ICS, an estimate was made of the annual firewood consumption before and after the installation of ICS:

$$C_S = 365\, c_S\, f_S\, N_S \tag{1}$$

$$C_M = 365\, c_M\, f_M\, N_M \tag{2}$$

$$C_L = 365\, c_L\, f_L\, N_L \tag{3}$$

$$C = C_S + C_M + C_L, \tag{4}$$

where C is annual firewood consumption, C_S, C_M and C_L are annual firewood consumption of small, medium and large households, respectively; c_S, c_M and c_L are per capita daily firewood consumption of small, medium and large households respectively; f_S (=2.5), f_M (=6.5) and f_L (=10.5) are average household sizes of small, medium and large households respectively; N_S, N_M and N_L are numbers of the small, medium and large households, respectively.

The annual saving on firewood is estimated as

$$S = C_i - C_{f,} \tag{5}$$

where C_i is the estimated annual firewood consumption before installation of ICS and C_f is the estimated annual firewood consumption after installation of ICS.

The decrease in firewood consumption for small, medium and large households was estimated based on the number of households in each category in the village. The total decrease in annual firewood consumption was estimated by summing this figure over all the villages.

The total estimated firewood consumption for the households in which the ICS were distributed was 4,642 tons before the installation of ICS and 3,471 tons after the installation of ICS, giving an annual saving of 1,171 tons in the 12 project villages, which was 25.2% of the firewood consumption (Table 3). The total population for the 1,098 households where ICS was distributed was 5,326. Thus, the average per capita firewood consumption was 2.39 kg/day before installation of ICS and 1.78 kg/day after installation of ICS, indicating an average per capita firewood saving of 0.61 kg/day. Wood contains significant amounts of moisture, which does not contribute to CO_2 emission upon burning the firewood. Assuming a moisture content of 9% (Wilson et al., 2016), and 50% carbon content (Chow & Rolfe, 1989), in the wood, and complete combustion of the wood, the installation of ICS is estimated to have reduced CO_2 emissions by 1,953 tons annually in the 12 project villages.

The time required for cooking was measured before and after the introduction of the ICS. There was a decrease in the time required to cook a meal using the ICS. The average cooking time estimated by the beneficiaries for cooking a meal was 117 minutes using traditional cook stoves. The average estimated cooking time decreased to 77 minutes using the ICS. There was an average decrease of 40 minutes in the cooking time due to the increased cook stove. In an opinion survey, 94% of households reported saving in the quantity of firewood consumed, 92% of households reported a decrease in smoke and 94% of the households reported a decrease in time taken for cooking (Table 4). The ICS, therefore, provided multiple benefits to the households where it was installed, which was acknowledged by the households.

Conclusion

Our study showed the high acceptability of the cement ICS in the project villages. The study showed that if the requirements of users are taken into consideration, it

Table 3. Estimate of Firewood Conserved Annually Due to Installation of the ICS.

	Annual Firewood Consumption (Tons/Year)		
Village Name	Before ICS	After ICS	Saving
Bibamal	436	326	110
Chaurakund	733	550	183
Chilati	270	200	70
Dhokda	62	46	16
Golai	1,288	963	325
Raipur	536	402	134
Khokmar	292	219	73
Kuhi	190	142	48
Malur	399	298	101
Chopan	167	125	42
Tangda	169	125	44
Rangubeli	100	75	25
Total	4,642	3,471	1,171

Source: The authors.

Table 4. Opinion Survey of Beneficiary Households.

	Perception		
Assessment Factors	Decreased (%)	No Change (%)	Increased (%)
Firewood consumed by ICS	94	6	0
The smoke released from ICS	92	6	0
Time required for cooking using ICS	94	8	0

Source: The authors.

is possible to develop ICS that are acceptable to the community. The cement model of ICS developed through the project was found to be durable, portable and helped to reduce firewood consumption, and provided health benefits to the user. A decrease in firewood consumption, and consequently CO_2 emissions, was a major benefit of installing ICS. Along with other measures for reducing firewood consumption being promoted in India, such as LPG, there is a place for ICS in remote forest villages, where LPG distribution is difficult and poverty discourages people from purchasing LPG.

Acknowledgements

The authors thank all the funding agencies whose generous support enabled this study. KFW bank, through IUCN, gave a grant that supported this project from 2017 to 2019. A grant by WWF-India supported parts of this project from 2016 to 2019. Maharashtra Forest Department was the nodal agency for the KFW-sponsored project and sponsored the installation of some improved cookstoves. The authors thank Samuchit Envirotech for their

guidance in the initial stages of the project. We thank Jitendra Dhikar and Radha Kasdekar for their help in measuring firewood consumption.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding

The authors received no financial support for the research, authorship and/or publication of this article.

References

Adler, T. (2010). Better burning, better breathing: Improving health with cleaner cook stoves. *Environmental Health Perspectives*, *118*(3), A124–129. https://doi.org/10.1289/ehp.118-a124

Amegah, A. K., & Jaakkola, J. J. (2016). Household air pollution and the sustainable development goals. *Bulletin of the World Health Organization*, *94*(3), 215–221. https://doi.org/10.2471/BLT.15.155812

Arnold, J., Köhlin, G., & Persson, R. (2006). Woodfuels, livelihoods, and policy interventions: Changing perspectives. *World Development*, *34*(4), 596–611. https://doi.org/10.1016/j.worlddev.2005.08.008

Bailis, R., Cowan, A., Berrueta, V., & Masera, O. (2009). Arresting the killer in the kitchen: The promises and pitfalls of commercializing improved cookstoves. *World Development*, *37*(10), 1694–1705.

Bhojvaid, V., Jeuland, M., Kar, A., Lewis, J. J., Pattanayak, S. K., Ramanathan, N., Ramanathan, V., & Rehman, I. H. (2014). How do people in rural India perceive improved stoves and clean fuel? Evidence from Uttar Pradesh and Uttarakhand. *International Journal of Environmental Research and Public Health*, *11*(2), 1341–1358. https://doi.org/10.3390/ijerph110201341

Bonjour, S., Adair-Rohani, H., Wolf, J., Bruce, N. G., Mehta, S., Prüss-Ustün, A., Lahiff, M., Rehfuess, E. A., Mishra, V., & Smith, K. R. (2013). Solid fuel use for household cooking: Country and regional estimates for 1980–2010. *Environmental Health Perspectives*, *121*(7), 784–790. https://doi.org/10.1289/ehp.1205987

Chandramouli, C. (2011). *Atlas on houses, household amenities and assets data 2001–2011: Visualizing through maps*. Census of India. Retrieved June 11, 2018, from https://dokumen.tips/documents/houses-household-amenities-and-assets-data-2001-2011-.html?page=1.

Chow, P., & Rolfe, G. L. (1989). Carbon and hydrogen contents of short-rotation biomass of five hardwood species. *Wood and Fiber Science*, *21*(1), 30–36.

De, U. K., & Chauhan, K. (2015). Degradation of forest and biodiversity in Sariska National Park, India and the responsible factors. *International Journal of Environment and Sustainable Development*, *14*(4), 398–426.

DeFries, R., & Pandey, D. (2010). Urbanization, the energy ladder and forest transitions in India's emerging economy. *Land Use Policy*, *27*(2), 130–138. https://doi.org/10.1016/j.landusepol.2009.07.003

Food and Agriculture Organization. (2010). *What woodfuels can do to mitigate climate change*. Food and Agriculture Organization of The United Nations. https://www.fao.org/publications/card/en/c/4b97b640-0c9b-5a7b-865d-

f976d2290973/#:~:text=Abstract%3A,carbon%20intensive%20than%20fossil%20fuels.

Government of Maharashtra. (2012). Dr. Shyamaprasad Mukherjee Jan Van Vikas Yojana, Goverment Resolution No. FDM 2012/Desk-4/F-2 dated 10 July 2012.

Jeuland, M. A., & Pattanayak, S. K. (2012). Benefits and costs of improved cookstoves: Assessing the implications of variability in health, forest and climate impacts. *PLoS ONE*, *7*(2), e30338. https://doi.org/10.1371/journal.pone.0030338

Khandelwal, M., Hill, M. Jr., Greenough, P., Anthony, J., Quill, M., Linderman, M., & Udaykumar, H. (2016). Why have improved cook-stove initiatives in India failed? *World Development*, *9*(2), 13–27. http://doi.org/10.1016/j.worlddev.2016.11.006

Pande, R., Kalamkar, V., & Kshirsagar, M. (2018). Making the popular clean: improving the Traditional multipot biomass cookstove in Maharashtra, India. *Environment, Development and Sustainability*, *21*(5), 1391–1410. https://doi.org/10.1007/s10668-018-0092-4

Patnaik, S., Tripathi, S., & Jain, A. (2019). *Roadmap for access to clean cooking energy in India*. Council on Energy, Environment and Water. https://www.ceew.in/publications/roadmap-access-clean-cooking-energy-india-0#:~:text=Overview,principles%20of%20equity%20and%20inclusion

Pattanayak, S. K., Jeuland, M., Lewis, J. J., Usmani, F., Brooks, N., Bhojvaid, V., Kar, A., Lipinski, L., Morrison, L., Patange, O., Ramanathanj, N., Rehmank, I. H., Thadanil, R., Voram, M., & Ramanathann, V. (2019). Experimental evidence on promotion of electric and improved biomass cookstoves. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(27), 13282–13287.

Popp, J., Kovács, S., Oláh, J., Divéki, Z., & Balázs, E. (2021). Bioeconomy: Biomass and biomass-based energy supply and demand. *New Biotechnology*, *60*, 76–84. https://doi.org/10.1016/j.nbt.2020.10.004

Shastri, C., Sangeetha, G., & Ravindranath, N. (2002). Dissemination of efficient ASTRA stove: Case study of a successful entrepreneur in Sirsi, India. *Energy for Sustainable Development*, *6*(2), 63–67. https://doi.org/10.1016/S0973-0826(08)60316-6

Shrimali, G., Slaski, X., Thurber, M. C., & Zerriffi, H. (2011). Improved stoves in India: A study of sustainable business models. *Energy Policy*, *39*(12), 7543–7456.

Smith, K. R., Uma, R., Kishore, V., Zhang, J., Joshi, V., & Khalil, M. (2000). Greenhouse implications of household stoves: An analysis for India. *Annual Review of Energy and the Environment*, *25*(1), 741–763.

Thakur, M., Schayck, C. P., & Boudewijns, E. A. (2019). Improved cookstoves in low-resource settings: A spur to successful implementation strategies. *NPJ Primary Care Respiratory Medicine*, *29*, Article 36. https://doi.org/10.1038/s41533-019-0148-4

Tyagi, D. K. (2014). *Tiger Conservation Plan: Core Plan, Plan period 2014–2015 to 2023–24*. Melghat Tiger Reserve.

Wilson, D. L., Talancon, D. R., Winslow, R. L., Linares, X., & Gadgil, A. J. (2016). Avoided emissions of a fuel-efficient biomass cookstove dwarf embodied emissions. *Development Engineering*, *1*, 45–52. https://doi.org/10.1016/j.deveng.2016.01.001

Win, Z. C., Mizoue, N., Ota, T., Kajisa, T., & Yoshida, S. (2018). Consumption rates and use patterns of firewood and charcoal in urban and rural communities in Yedashe Township, Myanmar. *Forests*, *9*(7), 429. https://doi.org/10.3390/f9070429

World Health Organization. (2014). *Household health and air pollution*. Retrieved November 1, 2017, from http://www.who.int/mediacentre/factsheets/fs292/en/

Article

Identification and Characterisation of the Salt Tolerant Phosphate-Solubilising Bacterial Isolates for Enhancing Soil Fertility

Asia-Pacific Journal of Rural Development
32(1) 37–53, 2022

DOI: 10.1177/10185291221117197
journals.sagepub.com/home/jrd
SAGE

Ei Phyu Kyaw[1], Tin Mar Lynn[1], Sabai Thant[1], Nwe Nwe Aung[1], Nan Nan Oo[1], Kyaing Kyaing Win[1] and San San Yu[1]

Abstract

In this study, 13 bacteria were isolated from the agricultural soils of Kyaukse city, Myanmar, and out of these isolates, two bacteria isolates *viz*. JU-24 and JU-33 are found to be potent phosphate (P) solubilisers and are selected for further studies. These two isolates are identified as *Bacillus megaterium* based on the 16S rRNA gene sequence. When the growth rates of these two isolates were tested for salt tolerance, they could grow well in media with NaCl concentrations of 3%, 6% and 9%. For 0% and 3% NaCl concentrations, JU-33 (84.37 mg/L for 0% NaCl and 130.36 mg/L for 3% NaCl) showed higher P-solubilising efficiency than JU-24 (73.29 mg/L for 0% NaCl and 87.42 mg/L for 3% NaCl) for both NaCl concentrations when inoculated in $Ca_3(PO4)_2$ containing liquid medium. In media containing $AlPO_4$ and $FePO_4$ without NaCl, the P-solubilising activity of JU-24 is higher than JU-33 for these two substrates. Moreover, these strains showed noticeable levels of P solubilisation activity in the presence of various carbon sources indicating high P-solubilising efficacy. The soil inoculation experiment revealed that inoculating the experimental soil with JU-33 resulted in an obvious increase in available P, which increased from 13.08 mg/L in the non-inoculated soil to 18.40 mg/L in the inoculated soil with the bacterial isolate, JU-33. This study clearly showed that JU-24 and JU-33 isolates could be used as biofertilizers in ecological agricultural systems and may help to sustain environmental health and soil productivity. The use of biofertilizers can reduce the use of expensive chemical fertilisers, reducing planting costs and improving soil fertility through

[1] Microbiology Laboratory, Biotechnology Research Department, Ministry of Science and Technology, Kyaukse, Mandalay, Myanmar

Corresponding author:
Ei Phyu Kyaw, Microbiology Laboratory, Biotechnology Research Department, Ministry of Science and Technology, Kyaukse, Mandalay 100301, Myanmar.
E-mail: dr.eiphyukyaw@gmail.com

long-term use. Biofertilizers can help solve the problem of feeding an increasing global population at a time when agriculture is facing various environmental stresses and are affordable for low-income farmers.

Keywords

Bacillus megaterium, carbon sources, phosphate solubilising bacteria, salt-tolerant, P substrates

Introduction

Phosphate (P) is the second most important nutrient for plant growth, accounting for 0.2% (w/w) of plant dry weight (Maharajan et al., 2018). Nevertheless, only 0.1% of P can be utilised by plants, in the inorganic form either as primary orthophosphates ($H_2PO_4^-$) or secondary orthophosphates (HPO_4^{2-}) ions from the soil solution, rendering available P as a restrictive factor for plant growth (Lambers & Plaxton, 2018). It is contained within nucleic acids, enzymes, coenzymes, nucleotides and phospholipids. P is essential in every feature of plant growth and development, from the molecular level to many physiological and biochemical plant activities and P deficiency appears to reduce seed size, seed number and viability (Satyaprakash et al., 2017).

Most of the P (95%–99%) present in the soil is part of insoluble compounds and hence cannot be utilised by plants (Corona et al., 1996). The average P content in soil is nearly 0.05% (w/w) with the main two forms being inorganic P (Pi) and organic P (Po). Since P is a stable element in soils, it does not form a gas (such as ammonia), and therefore it cannot move far from where it is applied (Pande et al., 2017). The reason for the stability of P compounds in soils is that they are highly reactive and react rapidly with other compounds (such as Al^{3+}, Ca^{2+} and Fe^{3+}), which become increasingly insoluble in the soil (Frossard et al., 2000; Shen et al., 2013).

P released from organic P fraction is highly controlled by soil conditions such as moisture and temperature (Adhya et al., 2015). Both biotic and abiotic factors manage the consequences of P in soil solution. Abiotic stress imposed on plants by the environment may be either physical or chemical (such as salinity, drought, flooding, heavy metals, temperature, gases and nutrient deficiency or excess, while abiotic stress exposed to the crop plants is a biological unit like diseases, insects, etc. (Verma et al., 2013). Abiotic and biotic stresses cause yield reduction for plants; however, the intensity of these stresses varies with a number of soil and plant factors.

Soil salinisation has become a severe constraint for crop production worldwide, which is one of the most important factors that restrict plants' productivity and quality. It also spreads out in the world year to year. Soil salinisation is a global and dynamic problem and the accelerated rate of salinisation has also created food insecurity in several countries. The delta regions of India, Myanmar and Bangladesh which majorly contribute to world rice production are facing serious threats to food security due to the salinisation of coastal soil (Anwarul et al.,

2014; Munns & Tester, 2008; Szabo et al., 2016). According to Syers et al. (1994), salt-affected irrigated areas caused annual income losses in terms of $12 billion globally.

According to the Food and Agricultural Organization (FAO) report, more than 800 million hectares of land and 20% of irrigated agricultural land were affected by salinity around the globe in 2008 (Singh & Jha, 2016). All growth features and yield components decline under salinity in many plants (Munns & Tester, 2008; Shahbaz & Ashraf, 2013). It is reported that more than 50% of arable land will be affected due to salinisation by 2050. The main social consequences of soil salinisation involve a decline in agricultural harvest, low income, change in livelihood options and related social constraints (Qadir et al., 2014). To overcome the inadequate food requirements in the future, it is essential to look up remedial measures for agriculture and aquaculture under natural stresses like salinity. Sodium chloride is the main salt type in most saline soils, and its effect can be observed as decreased productivity or plant death. Soil salinity causes plant stress in the following two ways: (a) make it difficult to uptake water from the roots, and (b) generates plant toxicity by gathering high salt concentrations in the plant (Munns & Tester, 2008).

One approach to solving the salt stress problem is the use of plant growth-promoting bacteria (PGPB) that plays a significant role in enhancing plant growth and development both under non-stress and stress conditions by a number of direct and indirect mechanisms (Glick et al., 2007; Munns & Tester, 2008; Nadeem et al., 2010; Zahir et al., 2004). A small number of studies had found salt-tolerant bacteria in non-saline soil (Chen Qihui et al., 2010; Echigo et al., 2005). Unexpectedly, researchers discovered a large number of halophiles in non-saline soils, and among them, *Bacillaceae* was the most commonly occurring family. Therefore, this study was conducted to isolate and distinguish the most effective novel salt stress tolerant microorganisms from the rhizosphere of some vegetable plants, and to detect their P-solubilising ability. This study also examined the efficiency of these isolated bacteria in their P solubilising ability as inoculants on saline soils.

Materials and Methods

Sample Collection and Isolation of Phosphate Solubilising Bacteria

Soil samples were collected from agricultural soils of different areas of Kyaukse city, Myanmar. The plants were dug out, the excess bulk soil was removed by gently shaking, and the soil adhering to the root was considered as rhizosphere soil (von der Weid et al., 2000) and the soil was collected in sterilised plastic bags. The Pikovskaya's medium (PKV), consisting of yeast extract 0.50 (g/L), sucrose 10.00 (g/L), tricalcium phosphate (TCP) (Himedia) 5.00 (g/L), ammonium sulfate 0.50 (g/L), potassium chloride 0.20 (g/L), magnesium sulfate 0.10 (g/L), manganese sulfate 0.0001 (g/L), ferrous sulfate 0.0001 (g/L), agar 15 (g/L) dissolved in 1,000 mL distilled water was prepared. The pH of the media was

adjusted to 7.0 before autoclaving at 121°C and 15 lbs pressure for 15 min (Pikovskaya, 1948). After autoclaving, the media were well mixed and poured into sterile Petri plates (25 mL/plate) under a laminar flow hood, and allowed to solidify. The bacterial isolation protocol and determination of the P-solubilisation ability were performed as previously described by Chen et al. (2014). Each soil sample was homogenised in sterile distilled water and serially diluted. Aliquots of each dilution were spread on the PKV medium and incubated at 35^0C for 24–48 h. Colonies were selected based on the development of a clear halo; the colonies were further purified on Luria-Bertani (LB) agar, which consisted of tryptone 10 (g/L), yeast extract 5 (g/L) and sodium chloride 5 (g/L). Once purified, each isolate was lyophilised and also stored at -80^0C in the same medium with 20% (v/v) glycerol for further study.

Qualitative and Quantitative Measurement of Phosphate Solubilisation

The P-solubilising ability was determined by culturing the isolates at 35°C on PKV plates. Isolates were spot inoculated on the centre of the agar plate aseptically. All the plates were incubated at 35°C ± 2°C for 7 days. P solubilisation was indicated by a clear zone surrounding a growing colony (Pande et al., 2017). The vanadomolybdophosphoric yellow colour method (Subba Rao, 1982) was employed to quantitatively determine the P solubilisation. The quantitative bioassay of solubilised P by bacterial isolate was carried out in PKV broth containing $Ca_3(PO_4)_2$ (5000 mg/L) as P source. 10 mL of PKV broth medium containing 5,000 mg/L P in the form of $Ca_3(PO4)_2$ was inoculated with 0.1 mL of bacterial culture (inoculum adjusted to 2×10^8 CFU/mL) and incubated at 35 ± 2.0 ^{0}C for 14 days.

During incubation, 1 mL of the supernatant was taken out on the 3rd, 6th, 9th and 12th days. The supernatant was obtained by centrifugation at 10,000 rpm for 20 min and was passed through a Millipore filter whose pore size was 0.45 µm. Then 0.1 mL of the supernatant (filtered) was mixed with 0.25 mL of Barton's reagent and the volume was made up to 5 mL with double distilled water (ddw). After 10 min, the intensity of the yellow colour was read on the spectrophotometer (UV–VIS Spectrophotometer, Selecta, Spain) at 430 nm and the amount of P-solubilised was extrapolated from the standard curve. The experiments were conducted in triplicates and values were expressed as their mean.

Extraction of DNA, PCR Amplification and 16S rRNA Gene Sequencing

The isolated strains were identified by the 16S rRNA sequencing method, and DNA extraction was performed using the PrepMan reagent (Thermofisher Scientific, California, US). 16S rRNA was amplified by using the 16S rRNA

universal primers (Forward primer 5′-AGAGTTTGATCCTGGCTCAG-3′ and reverse primer 5′-TACGGYTACCTTGTTACGA CT-3′). The amplification cycle consisted of an initial denaturation step of 3 min at 93ºC, followed by 35 cycles of 30 sec at 95ºC (denaturation), 30 sec at 60ºC (annealing) and 30 sec at 72ºC (extension), with a final extension step for 3 min at 72ºC. PCR products were electrophoresed using 1% agarose stained with ethidium bromide (0.5 µg/mL) and visualised using a Gel luminax 312. PCR products of isolates were purified using PCR purification kit (ThermoFisher Scientific) according to the manufacturer's instructions and the amplified products were sequenced on the Sanger sequencing platform at Eurofins (France) for sequencing. All the bacterial isolates were classified by BLAST analysis of their respective 16S rRNA gene partial sequences.

Phylogenetic Analysis

Sequence data were compared visually and sequences were aligned using the Clustal X software and distances were calculated according to Kimura's two-parameter method (Kimura, 1980). Phylogenetic tree was produced using the neighbour-joining method (Saitou & Nei, 1987). Bootstrap analysis was based on 1,000 resamplings. The MEGA (Molecular Evolutionary Genetics analysis) 11.0.8 package was used for all phylogenetic analyses (Tamura et al., 2013). The final sequence was submitted to GenBank (Thompson et al., 1997).

Screening for Salinity Tolerance

LB agar medium plates were prepared with different sodium chloride (NaCl) concentrations, that is, 3%, 6% and 9%. All of the isolates were inoculated in LB medium broth with various NaCl concentrations. After overnight incubation, the bacterial population was determined using the serial dilution method. For each treatment, three replications were maintained. The Petri plates were incubated at $35 \pm 2\ ^0$C for 24–48 h. The growth rate of the bacteria in the different concentrations of NaCl was recorded and chosen for further study (Buchan, 2000; Caton et al., 2004).

Effect of NaCl on Bacterial Phosphate Solubilisation

The P solubilising activity of each strain was investigated by incubating the isolates at 35°C for 15 days in PKV medium supplemented with 3% NaCl and $Ca_3(PO_4)_2$ (0.5%) as a P source. In this case 3% NaCl was used because seawater has salinity between 3.1% and 3.8% and in most saline soils, sodium chloride is the main salt type, and its effect can cause a lowering in productivity or plant death (Munns & Tester, 2008).

Phosphate-Solubilisation Efficiency of Bacterial Isolates with Different P Sources

It is generally believed that phosphates of Fe(III) and Al are the main forms of phosphorus in acid soils. To screen for the substrate with the highest P-solubilising efficiency, the isolated strains were cultured in a PKV broth medium with $FePO_4$ and $AlPO_4$ as the P substrates for 12 days at 35°C. The P-solubilisation ability of the PSB was tested by the vanadomolybdophosphoric yellow colour method.

Phosphate-Solubilisation Activity on Different Carbon Sources

To determine the P-solubilising efficiency of selected bacteria, different carbon sources were used in PKV broth medium supplemented with $Ca_3(PO4)_2$ as a P source without amended NaCl. The carbon source in the medium (sucrose) was replaced by 1% (w/v) of either glucose, dextrose, lactose or mannitol individually. These media were used to study the effect of carbon sources on P solubilisation.

Soil Experiment

The saline soil was prepared by mixing 3 kg of soil with 1% NaCl. 3 kg soil was treated with 180 mL bacterial inoculum of selected bacterial strains (2×10^8 CFU/mL). The bacterial treatment of the soil was conducted monthly for the first three consecutive months. The experimental setup lasted for six months. Non-inoculated soil with NaCl served as negative control. The available P in the soil of each treatment group was determined by the vanadomolybdophosphoric yellow colour method after six months, and the treatments were replicated thrice for all treatments.

Results

The collected soil samples were evaluated in vitro for identifying P solubilising bacteria in PKV plates. A total of 13 P-solubilising bacteria (PSB) were isolated on PKV agar medium, containing TCP as a substrate from the rhizospheric soils of paddy fields and screened for their P solubilising activities. Qualitative P-solubilisation potential was anticipated by observing the large clear halo zones around the bacterial colonies on PKV agar media. The qualitative screening results indicated that the isolates showed varying levels of P solubilising activities in PKV agar medium. Out of 13 bacterial isolates, 2 isolates (JU-24 and JU-33) were found to be more able to solubilise TCP than the other isolates (Figure 1).

The vanadomolybdophosphoric yellow colour method (Subba Rao, 1982) was used for quantitative estimation of P solubilisation. As shown in Figure 2, the P-solubilisation activity is low in the first three days of incubation and then the

solubilisation activity becomes high, reaching the highest level of 73.29 mg/L and 84.37 mg/L in 9 days for the bacterial strains JU-24 and JU-33, respectively, after which no further change in soluble P concentration was observed (data not presented).

The BLAST results of the most promising two bacterial isolates JU-24 and JU-33 showed more than 99% similarities with *Bacillus megaterium* between available GenBank entries in which JU-24 and JU-33 were identified as *B. megaterium* JU-24 and *B. megaterium* JU-33 strains. The 16S rRNA sequence of the strain JU-24 and JU-33 was deposited in GenBank under accession numbers

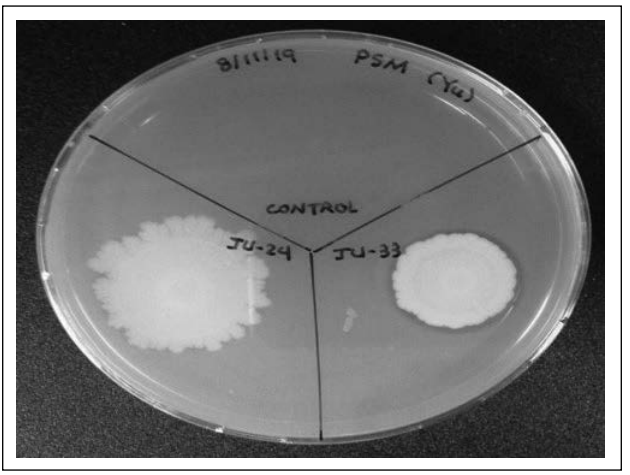

Figure 1. Screening of Phosphate Solubilising Activity by Culturing at 35°C on the PKV Media with Tricalcium Phosphate ($Ca_3(PO_4)_2$) After 7 Days Incubation.

Source: The authors.

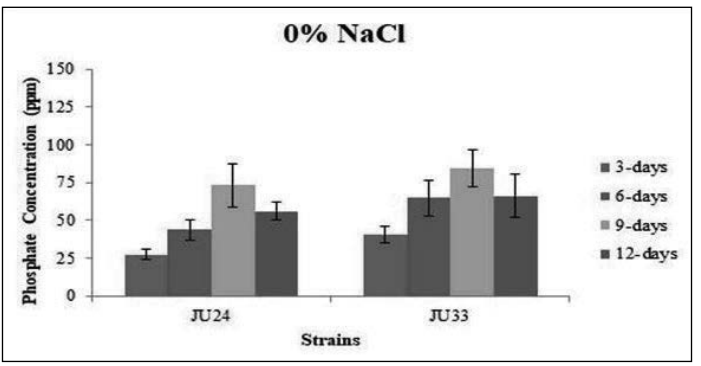

Figure 2. Phosphate Solubilising Activities of the Isolates without NaCl with $Ca_3(PO4)_2$ as P Source After 12 Days Incubation at 35^0C. Data Represent the Mean ± *SE* (*n* = 3).

Source: The authors.

MN902135 and MZ960379, respectively. Figure 3 shows a phylogenetic tree including the isolates JU-24 and JU-33 from this study and a few closely related sequences of *Bacillus* obtained from NCBI (National Center for Biotechnology Information). The number beside the node is the statistical bootstrap value. In brackets are the GenBank accession numbers of the 16S rRNA genes.

The isolates JU-24 and JU-33 were screened for their salinity tolerance at 3%, 6% and 9% NaCl concentration in LB medium. All isolates showed strong resistance to NaCl, even at a concentration of 9% NaCl (Table 1). The growth of P-solubilising strains was observed to gradually decrease with increasing NaCl concentrations. The optimal bacterial population for strain JU-24 and JU-33 were 3.2×10^6 CFU/mL and 7.0×10^6 CFU/mL, respectively, at 0% NaCl (Table 1).

The P solubilisation efficiency of the isolates JU-24 and JU-33 was tested, which varied from 27.59 to 87.42 mg/L and 50.02 to 130.36 mg/L for JU-24 and JU-33, respectively, under salt stress (3% NaCl) (Figure 4). The P solubilisation activities were increased significantly by the two isolates with increasing NaCl concentrations. In the current study, two bacterial isolates (JU-24 and JU-33) confirmed detectable levels of P-solubilisation even at high salt concentrations (3% NaCl) (Figures 2 and 4).

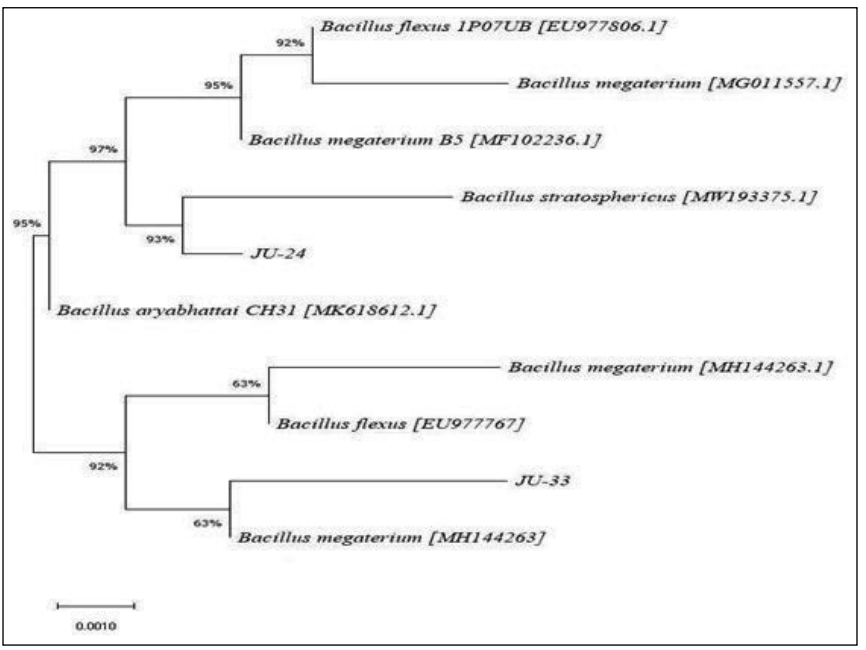

Figure 3. Phylogenetic Tree Based on 16S rDNA Gene Sequences Showing the Position of *Bacillus Megaterium* (JU-24) and *Bacillus Megaterium* (JU-33) Strains with Regard to Related Species, Using the Neighbour-Joining Method Included in the MEGA 11.0.8 Software Package.

Source: The authors.

Table 1. Bacterial Population of Isolated Strains on LB Plates for Different NaCl Stress Level. The Petri Plates Were Incubated at 35 ^{0}C for 24–48 h.

	Bacterial Population (CFU/mL)			
Strain	0% NaCl	3% NaCl	6%NaCl	9% NaCl
JU-24	3.2×10^6	7.2×10^5	3.8×10^5	5.2×10^4
JU-33	7.0×10^6	4.8×10^5	3.8×10^5	5.0×10^4

Source: The authors.

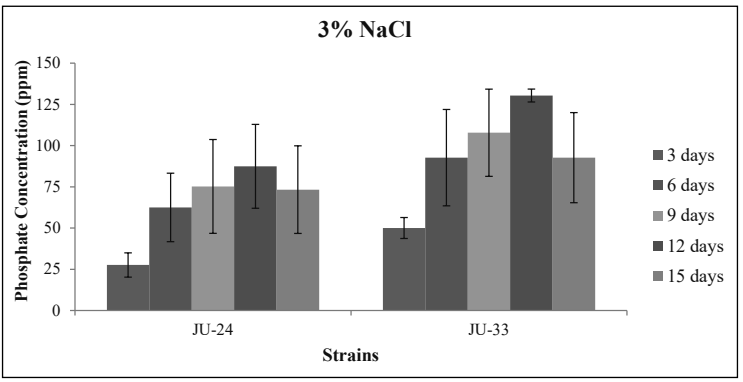

Figure 4. Phosphate Solubilising Activities of the Isolates with 3% NaCl with $Ca_3(PO4)_2$ After 15 Days Incubation at 35^{0}C. Data Represent the Mean ± *SE* (*n* = 3).

Source: The authors.

It was found that the two isolates JU-24 and JU-33 were capable of solubilising both $AlPO_4$ and $FePO_4$. The P-solubilisation of $AlPO_4$ by JU-24 was 45.87 mg/L at 9 days after the incubation and 42.54 mg/L by JU-33 at 9 days after the incubation. Similarity, the P-solubilising efficiency of JU-24 in $FePO_4$ substrate was 23.15 mg/L at 9 days after the incubation and by JU-33 was 8.47 mg/L at 9 days after the incubation.

Thus, when compared to the other tested P sources ($AlPO_4$ and $FePO_4$), the efficiency of P-solubilisation on $Ca_3(PO_4)_2$ was the highest (Figures 2, 5 and 6). Notably, JU2-4 showed higher P-solubilising efficiency than JU-33 for $AlPO_4$ and $FePO_4$ substrates.

P-solubilising abilities of JU-24 and JU-33 were tested in the presence of five carbon sources (glucose, sucrose, mannitol, dextrose and lactose). These isolates utilised all carbon sources for P solubilisation (Figure 7). The bacterial isolates had the highest P solubilising activity when glucose was used as the carbon source.

In this experiment, the available P of the soil from the treatments was measured by the vanadomolybdate method after six months. According to our findings, the available P in saline soil with bacterial inoculation (JU-33) is significantly higher than in saline soil without bacterial inoculation (Figure 8).

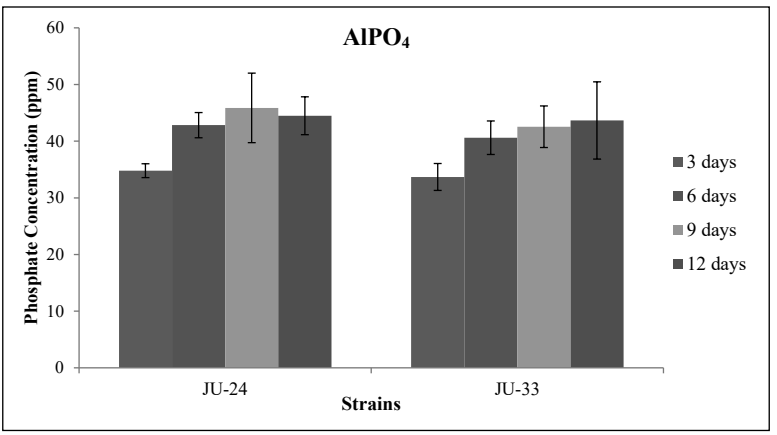

Figure 5. Phosphate Solubilising Activities of the Isolates Supplemented with $AlPO_4$ as P Source After 12 Days Incubation at 35^0C. Data Represent the Mean ± *SE* (*n* = 3).

Source: The authors.

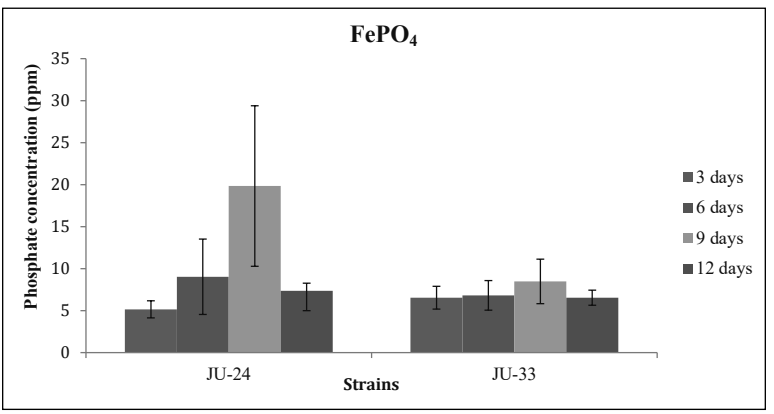

Figure 6. Phosphate Solubilising Activities of the Isolates Supplemented with $FePO_4$ as P Source After 12 Days Incubation at 35^0C. Data Represent the Mean ± *SE* (*n* = 3).

Source: The authors.

Discussions

P is an important nutrient for plants. But a considerable amount of P is bound in the soil environment which is not available for plants. One way of making this bound P available to the plants is to solubilise them. The application of PGPB seems to be an effective way to solubilise the bound P in soil. The two bacterial isolates were found to be efficient P solubilisers based on the formation of the clear zones and it could be attributed to the production of organic acids, production

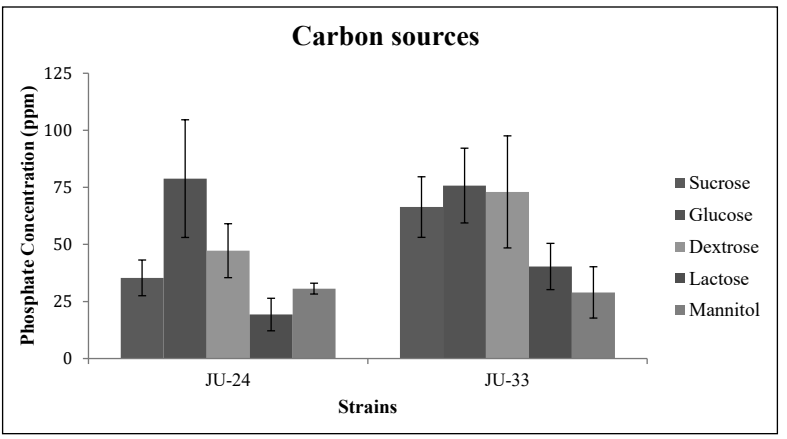

Figure 7. Phosphate Solubilising Activities of the Isolates Supplemented with Different Carbon Sources After Nine Days Incubation at 35^{0}C. Data Represent the Mean ± *SE* (*n* = 3).

Source: The authors.

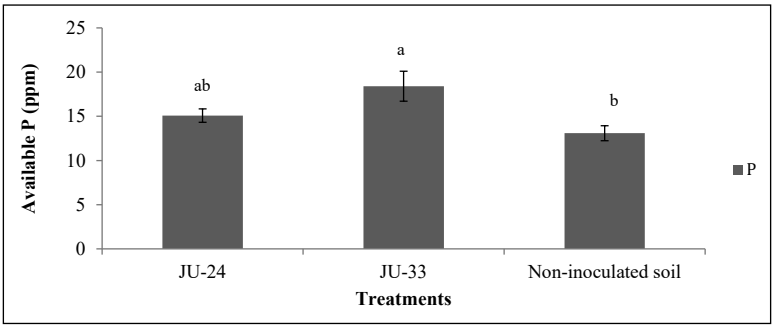

Figure 8. Available P in Soil After Six Months Incubation. Data Represent the Mean ± *SE* (*n* = 3).

Source: The authors.

of polysaccharides or the activity of phosphatase enzymes of P solubilising bacterial strains (Paul & Sinha, 2013). PSB may secrete some metabolites into surroundings in the course of their growth, which can solubilise P or organophosphate (Piccini & Azcon, 1987).

Under salt stress, plant growth can be affected by many factors such as ion toxicity, physiological disorders, hormonal variation and sensitivity to diseases. Stress tolerance towards high salt, pH and temperature may be the key factors for the survival, multiplication and growth of bacterial strains in alkaline soils. Soils poor in organic matter are known to be low in microbial activities, except in the rhizosphere of growing plants (Dadarwal, 1997). Hence, it is essential to find a

low-cost biological strategy for salinity stress control, which could be utilised without inhibiting the sustainability issues and environmental ethics. Because of the difficulties mentioned above, this research was conducted.

In this respect, PSB could be a promising tool in the mitigation of salinity stress in plants (Sharma & Baishya, 2017). Two bacterial strains were selected from the initial thirteen isolates, based on their clear zone formation. The P solubilising activity of strains varied with respect to optimal conditions required for each strain. All of the strains in this study achieved optimal P solubilisation levels by the ninth day for all P sources without amended NaCl. Louw and Webley (1959) and Leyval and Berthelin (1989) also reported that many isolates did not show any clear zone on agar plates indicating solubilisation of insoluble inorganic Ps in solid media. This may be due to the varying diffusion rates of different organic acids, production of polysaccharides and the activity of phosphatase enzymes secreted by an organism (Johnston, 1952). In this study, the two selected isolates were able to maintain a high bacterial population at 9% of NaCl-amended media, which is similar to the findings of a previous report (Qurashi & Sabri, 2011). There was no zone of clearance at 9% NaCl, but colony growth was observed.

The selected PGPB isolates were identified using the 16S rRNA gene sequence, and comparison with the NCBI database revealed more than 99% similarities to *B. megaterium*. *Bacillus* is a well-known genus categorised as PGPB, and it is also one of the major genus exhibiting P solubilising ability under saline soil conditions (Damodaran et al., 2019). Nautiyal et al. (2000) also reported that bacterial strains with their genetic potential for increased tolerance to high salt and high temperature can increase crop production in semi-arid and arid regions of the world. In this study, all the isolates were measured for quantitative P-solubilisation with 3% NaCl concentration, and it was found that all the isolates showed more P solubilising activity than those without NaCl concentration. In the present study, the isolates showed more P solubilising activity with increasing concentration of NaCl. These findings are consistent with the results of previous studies showing that the PSB requires NaCl for better solubilisation of inorganic P (Gupta et al., 2012). However, Jiang et al. (2019) reported that salt concentrations >0.4 M decreased P solubilisation activity of the stress-tolerant P-solubilising strains. However, all the tested PSB in this study showed high P-solubilising ability even under 0.5 M NaCl.

Beneficial microbes such as those in the genera *Bacillus* (Prabhu et al., 2018) and *Enterobacter* spp. Kim et al. (2014) have been described to increase plant growth under salt-stress conditions. TCP is the inorganic insoluble P compounds in the soil, which is not easily soluble and P from this source can easily not be assimilated by plants (Patel et al., 2016). Insoluble inorganic P compounds such as TCP, dicalcium phosphate, aluminium phosphate and ion phosphate can be solubilised by certain bacterial strains belonging to genera *Pseudomonas, Bacillus, Rhizobium, Burkholderia, Achromobacter, Agrobacterium, Micrococcus, Aerobacter, Flavobacterium* and *Erwinia* (Rodríguez & Fraga, 1999). Over 80% of the P in cropland soil is Pi and they are in various forms such as calcium and magnesium phosphate, which are dominant in some types of soil, while ferric and

aluminium phosphate are more abundant in others (Yu et al., 2012). Therefore, in this research, we studied the potential of the isolated strains to solubilise aluminium and iron phosphate and we found that they can solubilise these two substrates. According to Rodríguez and Fraga (1999), *B. megaterium* is one of the most powerful P solubilisers, and it was discovered that TCP can be easily degraded by these isolates when compared to iron and aluminium phosphate in our study. As heterotrophic bacteria, P solubilisers require carbon source and energy for both the synthesis of new cell material and the oxidation of carbon compounds. Therefore, the role of carbon sources is of utmost significance.

In rhizosphere soils water-soluble C compounds mainly as carbohydrates and organic acids and a small portion of amino acids are present. It was well known that a higher number of microorganisms are associated with the plant rhizosphere due to its carbon concentration (Nahas, 2007). In the present study, it was found that glucose is the most favoured carbon source for maximum solubilisation of P by these two isolates, when TCP is used, followed by lactose and then sucrose and similar results have been reported for *Aspergillus* by Rathore (2012). Thus, simple sugar (glucose) is preferred to other sugars for these two isolates.

However, the viability and sustainability of PSB technology largely depend on the development and distribution of good quality PSB inoculants to farming communities. Therefore, we need to identify and characterise more PSB with high efficiency for their application under various field conditions. The use of PSB in agricultural soils is a low-cost technology and environmentally friendly approach, which does not disturb ecological balances (Das et al., 2007). Many PSBs are proved to be effective biofertilizers or bio-controlling agents especially *B. megaterium, Bacillus circulans, Bacillus subtilis and Pseudomonas striata* are effective biofertilizers (Satyaprakash et al., 2017).

Conclusions

In conclusion, two locally isolated PGPB strains were isolated from agricultural soils and identified as *B. megaterium,* which exhibited salt tolerance at 9% NaCl concentration and they can solubilise P solubilising activities under saline conditions. It was found that these two isolates can solubilise most of the P-substrates ($Ca_3(PO_4)_2$, $AlPO_4$ and $FePO_4$). Hence, the two salt-tolerant PSB have the potential to be used as biofertilizers for saline soils. One of the fundamental components of sustainable agriculture production is soil fertility management using microbial fertilisers. As a result, proper formulation of saline tolerant P-solubilising bacterial bio-inoculants for saline soil and other problematic areas in the country is critical. Further research is required to replenish treatment of the bacterial inoculation to the saline soil until the plants can survive on it.

Although the marketing of biofertilizers is not advanced in Myanmar, biofertilizers are low-cost inputs with significant environment-friendly benefits, enormous potential in enhancing crop productivity and are a viable alternative to high chemical inputs. Therefore, the use of biofertilizers can reduce the use of

expensive chemical fertilisers, reducing planting costs and improving soil fertility through long-term use. Biofertilizers can help solve the problem of feeding an increasing global population at a time when agriculture is facing various environmental stresses and are affordable for low-income farmers. Selling chemical-free products can increase farmers' incomes. The biofertilizer's technological development was dependent on cooperation between the government and the farmers for sustainable agriculture.

Acknowledgements

This work was supported by Ministry of Science and Technology, Myanmar. The authors sincerely thank Professor Dr. Aye Aye Khai, Director General, Biotechnology Research Department (BRD), for her guidance and support. The authors thank to their colleagues at Microbiology Laboratory, Biotechnology Research Department, Ministry of Science and Technology, Myanmar.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by Microbiology laboratory, Biotechnology Research Department, Ministry of Science and Technology, Myanmar.

References

Adhya, T. K., Kumar, N., Reddy, G., Podile, A. R., Bee, H., & Samantaray, B. (2015). Microbial mobilization of soil phosphorus and sustainable P management in agricultural soils. *Current Science*, *108*(7), 1280–1287.

Anwarul, A. M., Habiba, U., & Shaw, R. (Eds.). (2014). Salinity scenario in Mekong, Ganges, and Indus River Deltas. In *Water insecurity: A social dilemma* (Vol. *13*, pp. 115–138). Emerald Group Publishing Limited.

Buchan, J. (2000). Health sector reform and human resources: Lessons from the United Kingdom. *Health Policy and Planning*, *15*(3), 319–325.

Caton, T. M., Witte, L. R., Ngyuen, H. D., Buchheim, J. A., Buchheim, M. A., & Schneegurt, M. A. (2004). Halotolerant aerobic heterotrophic bacteria from the Great Salt Plains of Oklahoma. *Microbial Ecology*, *48*(4), 449–462.

Chen, Q., Liu, S., Bai, Y., Li, Y., Gao, C., & Zhang, Q. (2014). Screening and identification of phosphate-solubilizing bacteria from reclaimed soil in Shanxi mining area. *Plant Nutrition and Fertilizer Science*, *20*, 1505–1516.

Chen, Q., Liu, Z., Peng, Q., Huang, K., He, J., Zhang, L., Li, W., & Chen, Y. (2010). [Diversity of halophilic and halotolerant bacteria isolated from non-saline soil collected from Xiaoxi National Natural Reserve, Hunan Province]. *Wei sheng wu xue bao = Acta microbiologica Sinica*, *50*(11), 1452–1459.

Corona, M. E. P., Pérez Corona, M. E., Van Der Klundert, I., & Verhoeven, J. T. A. (1996). Availability of organic and inorganic phosphorus compounds as phosphorus sources for Carex species. *New Phytologist*, *133*(2), 225–231. https://doi.org/10.1111/j.1469-8137.1996.tb01889.x

Dadarwal, K. R. (1997). *Biotechnological approaches in soil microorganisms for sustainable crop production*. Scientific publishers.

Damodaran, T., Mishra, V. K., Jha, S. K., Pankaj, U., Gupta, G., & Gopal, R. (2019). Identification of rhizosphere bacterial diversity with promising salt tolerance, PGP traits and their exploitation for seed germination enhancement in sodic soil. *Agricultural Research*, *8*(1), 36–43.

Das, S., Lyla, P. S., & Khan, S. A. (2007). Biogeochemical processes in the continental slope of Bay of Bengal: I. Bacterial solubilization of inorganic phosphate. *Revista de Biologia Tropical*, *55*(1), 1–9.

Echigo, A., Hino, M., Fukushima, T., Mizuki, T., Kamekura, M., & Usami, R. (2005). Endospores of halophilic bacteria of the family Bacillaceae isolated from non-saline Japanese soil may be transported by Kosa event (Asian dust storm). *Saline Systems*, *1*, Article 8. https://doi.org/10.1186/1746-1448-1-8

Frossard, E., Condron, L. M., Oberson, A., Sinaj, S., & Fardeau, J. C. (2000). Processes governing phosphorus availability in temperate soils. *Journal of Environmental Quality*, *29*(1), 15–23.

Glick, B. R., Cheng, Z., Czarny, J., & Duan, J. (2007). Promotion of plant growth by ACC deaminase-producing soil bacteria. In Bakker, P. A. H. M., Raaijmakers, J. M., Bloemberg, G., Höfte, M., Lemanceau, P., & Cooke, B. M. (Eds.), *New perspectives and approaches in plant growth-promoting rhizobacteria research* (pp. 329–339). Springer.

Gupta, M., Kiran, S., Gulati, A., Singh, B., & Tewari, R. (2012). Isolation and identification of phosphate solubilizing bacteria able to enhance the growth and aloin-A biosynthesis of Aloe barbadensis Miller. *Microbiological Research*, *167*(6), 358–363.

Jiang, H., Qi, P., Wang, T., Chi, X., Wang, M., Chen, M., Chen, N., & Pan, L. (2019). Role of halotolerant phosphate-solubilising bacteria on growth promotion of peanut (*Arachis hypogaea*) under saline soil. *Annals of Applied Biology*, *174*(1), 20–30. https://doi.org/10.1111/aab.12473

Johnston, H. W. (1952). *The solubilization of phosphate: 1.-The action of various organic compounds on dicalcium and tricalcium phosphates*. EV Paul, Government Print. http://digitallibrary.landcareresearch.co.nz/digital/collection/p20022coll20/id/143/

Kim, K., Jang, Y.-J., Lee, S.-M., Oh, B.-T., Chae, J.-C., & Lee, K.-J. (2014). Alleviation of salt stress by enterobacter sp. EJ01 in tomato and Arabidopsis is accompanied by up-regulation of conserved salinity responsive factors in plants. *Molecules and Cells*, *37*(2), 109–117.

Kimura, M. (1980). A simple method for estimating evolutionary rates of base substitutions through comparative studies of nucleotide sequences. *Journal of Molecular Evolution*, *16*(2), 111–120.

Lambers, H., & Plaxton, W. C. (Eds.). (2018). Phosphorus: Back to the roots. In *Annual plant reviews* (pp. 3–22). John Wiley & Sons. https://onlinelibrary.wiley.com/doi/abs/10.1002/9781118958841.ch1

Leyval, C., & Berthelin, J. (1989). Interactions between *Laccaria laccata, Agrobacterium radiobacter* and beech roots: Influence on P, K, Mg, and Fe mobilization from minerals and plant growth. *Plant and Soil*, *117*(1), 103–110.

Louw, H. A., & Webley, D. M. (1959). A study of soil bacteria dissolving certain mineral phosphate fertilizers and related compounds. *The Journal of Applied Bacteriology*, *22*(2), 227–233.

Maharajan, T., Ceasar, S. A., Krishna, T. P., Ramakrishnan, M., Duraipandiyan, V., Naif-Abdulla, A.-D., & Ignacimuthu, S. (2018). Utilization of molecular markers for improving the phosphorus efficiency in crop plants. *Plant Breeding*, *137*(1), 10–26.

Munns, R., & Tester, M. (2008). Mechanisms of salinity tolerance. *Annual Review of Plant Biology*, *59*, 651–681. https://doi.org/10.1146/annurev.arplant.59.032607.092911

Nadeem, S. M., Zahir, Z. A., Naveed, M., & Ashraf, M. (2010). Microbial ACC-deaminase: Prospects and applications for inducing salt tolerance in plants. *Critical Reviews in Plant Sciences*, *29*(6), 360–393.

Nahas, E. (2007). Phosphate solubilizing microorganisms: Effect of carbon, nitrogen, and phosphorus sources. In Velazquez, E., & Rodriguez-Barrueco, C. (Eds.), *First international meeting on microbial phosphate solubilization* (pp. 111–115). Springer.

Nautiyal, C. S., Bhadauria, S., Kumar, P., Lal, H., Mondal, R., & Verma, D. (2000). Stress induced phosphate solubilization in bacteria isolated from alkaline soils. *FEMS Microbiology Letters*, *182*(2), 291–296.

Pande, A., Pandey, P., Mehra, S., Singh, M., & Kaushik, S. (2017). Phenotypic and genotypic characterization of phosphate solubilizing bacteria and their efficiency on the growth of maize. *Journal of Genetic Engineering and Biotechnology*, *15*(2), 379–391.

Patel, K., Patel, S., Parekh, V., & Jha, S. (2016). Isolation and characterization of salt tolerant phosphate solubilizing Serratia marcescens isolated from coastal area. *Journal of Pure & Applied Microbiology*, *10*(3), 2401–2408.

Paul, D., & Sinha, S. N. (2013). Phosphate solubilization potential and phosphatase activity of some bacterial strains isolated from thermal power plant effluent exposed water of river Ganga. *CIBTech Journal of Microbiology*, *2*(3), 1–7.

Piccini, D., & Azcon, R. (1987). Effect of phosphate-solubilizing bacteria and vesicular-arbuscular mycorrhizal fungi on the utilization of Bayovar rock phosphate by alfalfa plants using a sand-vermiculite medium. *Plant and Soil*, *101*(1), 45–50.

Pikovskaya, R. I. (1948). Mobilization of phosphorus in soil connection with the vital activity of some microbial species. *Microbiology*, *17*, 362–370.

Prabhu, N., Borkar, S., & Garg, S. (2018). Phosphate solubilization mechanisms in alkaliphilic bacterium Bacillus marisflavi FA7. *Current Science*, *114*(4), 845–853. http://irgu.unigoa.ac.in/drs/handle/unigoa/5143

Qadir, M., Quillérou, E., Nangia, V., Murtaza, G., Singh, M., Thomas, R. J., Drechsel, P., & Noble, A. D. (2014). Economics of salt-induced land degradation and restoration. *Natural Resources Forum*, *38*(4), 282–295.

Qurashi, A. W., & Sabri, A. N. (2011). Osmoadaptation and plant growth promotion by salt tolerant bacteria under salt stress. *African Journal of Microbiology Research*, *5*(21), 3546–3554. https://academicjournals.org/journal/AJMR/article-abstract/554C39013319

Rathore, P. (2012). Role of different carbon sources in phosphate solubilization. *International Journal of Scientific Research*, *3*(2), 457–458. https://doi.org/10.15373/22778179/feb2014/18

Rodríguez, H., & Fraga, R. (1999). Phosphate solubilizing bacteria and their role in plant growth promotion. *Biotechnology Advances*, *17*(4–5), 319–339.

Saitou, N., & Nei, M. (1987). The neighbor-joining method: A new method for reconstructing phylogenetic trees. *Molecular Biology and Evolution*, *4*(4), 406–425. https://doi.org/10.1093/oxfordjournals.molbev.a040454

Satyaprakash, M., Nikitha, T., Reddi, E. U. B., Sadhana, B., & Vani, S. S. (2017). Phosphorous and phosphate solubilising bacteria and their role in plant nutrition. *International Journal of Current Microbiology and Applied Science*, *6*(4), 2133–2144.

Shahbaz, M., & Ashraf, M. (2013). Improving salinity tolerance in cereals. *Critical Reviews in Plant Sciences*, *32*(4), 237–249.

Sharma, P., & Baishya, R. (2017). Phosphate solubilizing bacteria-assisted salinity tolerance in plants: A review. *The Botanica*, *67*, 77–83. http://botany.du.ac.in/botanica/67/pdf/16.%20Prachi%20Sharma.pdf

Shen, J., Li, C., Mi, G., Li, L., Yuan, L., Jiang, R., & Zhang, F. (2013). Maximizing root/rhizosphere efficiency to improve crop productivity and nutrient use efficiency in intensive agriculture of China. *Journal of Experimental Botany*, *64*(5), 1181–1192.

Singh, R. P., & Jha, P. N. (2016). Alleviation of salinity-induced damage on wheat plant by an ACC deaminase-producing halophilic bacterium Serratia sp. SL-12 isolated from a salt lake. *Symbiosis*, *69*(2), 101–111.

Subba Rao, N. S. (1982). Phosphate solubilization by soil microorganisms. *Advances in Agricultural Microbiology/edited by NS Subba Rao*. http://agris.fao.org/agris-search/search.do?recordID=US201302590749

Syers, J. K., Rimmer, D. L., International, C. A. B., & Science., British Society of Soil (1994). *Soil science and sustainable land management in the tropics*. CAB International.

Szabo, S., Hossain, M. S., Adger, W. N., Matthews, Z., Ahmed, S., Lázár, A. N., & Ahmad, S. (2016). Soil salinity, household wealth and food insecurity in tropical deltas: Evidence from south-west coast of Bangladesh. *Sustainability Science*, *11*(3), 411–421.

Tamura, K., Stecher, G., Peterson, D., Filipski, A., & Kumar, S. (2013). MEGA6: Molecular evolutionary genetics analysis version 6.0. *Molecular Biology and Evolution*, *30*(12), 2725–2729.

Thompson, J. D., Gibson, T. J., Plewniak, F., Jeanmougin, F., & Higgins, D. G. (1997). The CLUSTAL_X windows interface: Flexible strategies for multiple sequence alignment aided by quality analysis tools. *Nucleic Acids Research*, *25*(24), 4876–4882.

Verma, S., Nizam, S., & Verma, P. K. (2013). Biotic and abiotic stress signaling in plants. In Sarwat, M., Ahmad, A., & Abdin, M. Z. (Eds.), *Stress signaling in plants: Genomics and proteomics perspective* (Vol. *1*, pp. 25–49). Springer New York.

von der Weid, I., Paiva, E., Nóbrega, A., van Elsas, J. D., & Seldin, L. (2000). Diversity of Paenibacillus polymyxa strains isolated from the rhizosphere of maize planted in Cerrado soil. *Research in Microbiology*, *151*(5), 369–381. https://doi.org/10.1016/s0923-2508(00)00160-1

Yu, Q., Ma, Z., Wang, J., & Wei, L. (2012). Screening of P solubilizing bacteria and its effects on transformation of soil inorganic P fractions. *Journal of Soil and Water Conservation*, *26*, 103–107.

Zahir, Z. A., Arshad, M., & Frankenberger, W. T. (2004). Plants growth promoting rhizobacteria: Applications and perspectives in agriculture. *Advances in Agronomy*, *81*, 97–168. http://doi.org/10.1016/S0065-2113(03)81003-9

Case Study

Rural Communication Services (RCS) and Appropriation of Flatbed Dryers among Farmers in Sto. Domingo, Nueva Ecija, Philippines

Asia-Pacific Journal of Rural Development
32(1) 54–63, 2022

DOI: 10.1177/10185291221112206
journals.sagepub.com/home/jrd
SAGE

C. A. N. Vallejo[1] and C. S. Torres[2]

Abstract

This study analyses the impact of rural communication services (RCS) on rice farmers' appropriation of flatbed dryers in Sto. Domingo, Nueva Ecija, Philippines. The study faces the problem from the sociopsychological lens of viewing communication problems. A survey of 131 rice farmers from three barangays in Sto. Domingo, Nueva Ecija, namely Pulong Buli, Mambarao and Malaya has been conducted to collect data. For the key informant interview (KII), informants/ interviewees were leaders of farmers' organisations, municipal agricultural officer, agricultural technicians, and flatbed dryer developers. The findings reveal that there is a source-driven orientation of communication services in the study area as the majority of the rice farmers passively receive information from different sources. The most accessed RCS provider was the municipal agriculture office. Farmers viewed that information as relevant to their needs because they were able to utilise them in their farming practices and they were compatible with the existing methods and practices. Most of the respondents were engaged in person-to-person communication in accessing information about the flatbed dryer. Attending seminars and training, cooperative assemblies and membership in Farmers' Field School (FFS) were among the opportunities where the respondents engaged in peer learning.

[1] Department of Communication and Development Studies, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines
[2] College of Development Communication, University of the Philippines Los Baños, Laguna, Philippines

Corresponding author:
C. A. N. Vallejo, Department of Communication and Development Studies, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Central Luzon 3120, Philippines.
E-mail: canvallejo@clsu.edu.ph

Keywords

Rural communication services (RCS), technology appropriation strategy, flatbed rice dryers, information sources

Introduction

Most of Filipino farmers rely on the Sun to dry their grain. However, with the current state of climate change, drying rice has become a challenging task. According to the international rice research institute (IRRI) (Paddy Drying, 2013), 'post-harvest procedures, losses to animals and pests, and inefficient rice mills all contribute to up to 30% post-harvest losses across Asia, Latin America and the Caribbean, and Africa'. Obviously, losses during rice drying is one of the aspects of post-harvest losses. Flatbed dryers have been developed in the Philippines to prevent such economic losses during the post-harvest procedure of rice by farmers. Rural communication services (RCS) promote the spreading of information in rural communities in the Philippines to facilitate farmers' equitable access to knowledge and information about mechanical drying. The concept of RCS was developed in the context of FAO-funded projects to promote network-like institutional arrangements that allow the integration of demand-driven communication services to meet the needs of knowledge and information of the rural people ensuring their active participation in the development initiatives (Food and Agricultural Organization [FAO], 2017).

RCS refers to 'two-way communication processes delivered on a regular basis to the rural population with the purpose of improving rural lifestyles through equitable access to knowledge and information, social engagement in decision-making, and greater links between rural institutions and local communities' (FAO, 2014). Information services include interpersonal, printed media, radio, mobile phones and computer services. These services aim to enhance farmers' appropriation of flatbed dryers. Meanwhile, appropriation is a 'dynamic and creative process that results in a wide range of usage and meaning patterns on a personal and communal level' (Wirth et al., 2006). Users must try to understand the technology in their own environment. The circumstances of a technological introduction into a user environment — or recontextualisation — are critical for its success. Users of technology play an active role in this process — they appropriate the technology, which means they research new technology and determine whether to incorporate it into their practices and routines (Janneck, 2009).

The Philippines' department of agriculture encourages farmers to adopt more effective drying technologies as part of attempts to improve mechanization in the rice sector, as outlined in the agriculture and fisheries mechanization (AFMech) law. Farmers can increase their profitability by lowering quantity and quality losses using flatbed drying. It broadens farmers' intertemporal options by allowing

them to store grains and seek better prices afterward without sacrificing quality. In line with the intensive effort of the government to mechanise agriculture, this study can contribute to determining the features or aspects of RCS leading to appropriation so that these features or aspects can be institutionalised. RCS is supposed to be a social intervention meant to enhance desired or proper appropriation. Hence, this study has an objective to determine how RCS influences the farmers' appropriation of flatbed dryers. Specifically, it aims to (a) describe the socio-demographic and farm-related profiles of rice farmers who use flatbed rice dryers, (b) analyse the features of the RCS to promote and distribute the flatbed dryers to the rice farmers and (c) explain how the rice farmers appropriate the flatbed dryers.

Conceptualisation and Methodology

This study on RCS and appropriation of flatbed dryers and farmers was conducted under the sociopsychological tradition of communication theory. According to Craig (1999), under the sociopsychological tradition, 'communication is the process by which humans engage and affect one another.' Craig and Muller (1999) also stated that 'psychological predispositions (attitudes, emotional states, personality traits, unconscious conflicts, social cognitions and so on) are mediated by social interaction, which is influenced by emergent factors such as media technologies and institutions, as well as interpersonal impact'. Communication is also considered as a process that can occur face-to-face or through technological medium and can flow from one to one, one to many, or many to many in the sociopsychological tradition. A function showing the factors that affect the appropriation of flatbed dryers is likely to strengthen the theoretical underpinnings. The sociopsychological tradition is useful in this study because it aims to explain the causes and effects of social conduct while also cultivating techniques aimed at exerting purposeful control over those behavioural causes and effects. Communication issues are thus viewed in the sociopsychological tradition as situations that necessitate the successful manipulation of behavioural causes to create objectively defined and measured consequences (Craig, 1999). RCS can be considered as a causal element in determining what will happen to the outcome, which is the rice farmers' use of flatbed dryers, in this study.

The study is descriptive in nature and the required data was collected based on different aspects of RCS and flatbed rice dryers over the period spanning from January to March 2019. A survey and key informant interviews were conducted at Sto. Domingo, Nueva Ecija, Philippines (Figure 1). Survey respondents were 131 rice farmers selected randomly, while key informant interviews were RCS providers. Survey data was encoded in a spreadsheet. Furthermore, the results of the key informant interviews (KII) were used as part of the triangulation and verification of survey results.

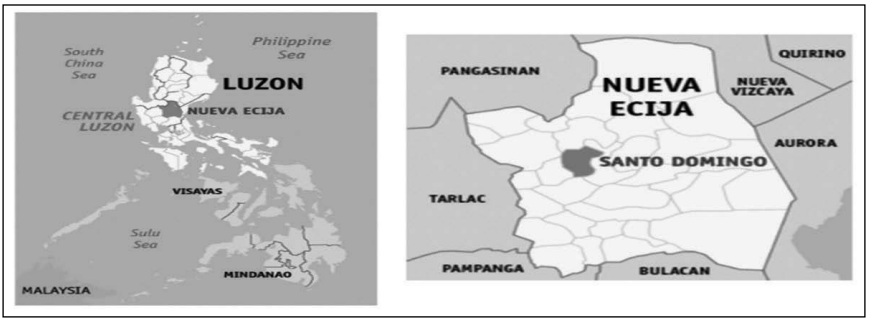

Figure 1. Map of the Philippines Showing Nueva Ecija (Left) and Map of Nueva Ecija Showing the Town of Sto. Domingo (Right).

Source: https://commons.wikimedia.org/wiki/File:Ph_locator_nueva_ecija_santo_domingo.png (Map of Nueva Ecija) and https://commons.wikimedia.org/wiki/File:Ph_locator_nueva_ecija.svg (Map of the Philippines).

Results and Discussion

Profile of Rice Farmers

The majority of the respondents are male (73%), married (79%), and educated up to high school level. Their average age is 58 years while the average household size is four. The data indicate that farming is still largely dominated by males; farming has been traditionally considered a strenuous job meant for men. Data on farmers' age reflect an aging population of rice farmers in Sto. Domingo, Nueva Ecjia. According to some of the respondents, it is common for the younger population in their locality to go to urban areas to look for other better jobs whereas the older population remains in the village and constitutes most of the farmers. In terms of the level of education, data implies that all of the respondents have formal schooling and the majority are fairly educated. This also goes to show that farmers' education has improved compared to the previous years, when farmers' education went up to some elementary years only. The mean household size is four, which is the typical size of a Filipino family.

The average size of the farmland of respondents is 1.5 hectares of land whereas the average years of farming is 32 years. This finding corresponds to Philippine data on farming, which shows that Filipino farmers are small-holding farmers, that is, the average farm size is 3.0 hectares or less. Data on the average years of farming suggests that the sampled rice farmers have extensive experience in rice farming and that they could have been farming all their life. Half of the respondents (50%) were not members of any organisation. For those few who were members of organisations, three agriculture-related organisations were mentioned. These were: Viga Costra irrigators' association, which is composed of farmers who benefit from the irrigation services provided by NIA; Pulong Buli multi-purpose cooperative, which deals with the production and marketing of onion and rice;

and Malaya irrigators association which is also composed of members who strive for sustainable operation and maintenance of irrigation systems.

Rural Communication Services (RCS) for the Flatbed Dryers

The respondents' mode of access to information that is, whether passively or proactively, is provided to describe the features of RCS involved in the appropriation of a flatbed dryer. Table 1 shows that the majority (74%) of the respondents passively received information from different sources. This implies a source-based orientation of communication services in the study area. Despite farmers' access to sources, most of them passively received agricultural information. The respondents have stated that they rely on and wait for agricultural technicians to give them information that they need to improve their farming practices or solve rice-farming problems. It can be said that communication services were source-oriented, with very few exceptions of respondents who proactively requested information from service providers. Agricultural information is often delivered in a top-down approach where farmers still view themselves as passive recipients of the information. It has been observed that service providers and farmers seem to have different views regarding the provision of information services. On the one hand, service providers believe that farmers can visit them in their offices and ask for services; they believe that this promotes empowerment and accountability. Farmers, on the other hand, believe that service providers should deliver the information in rural areas. The purpose of RCS is to provide farmers with knowledge and information that will allow them to make better decisions and boost their production and livelihood. Farmers are partners in communication services, so it is not simply a matter of advising them, it is also a matter of collaboration with them throughout the process (FAO, 2010).

RCS Providers Accessed by the Respondents

As shown in Table 2, it can be stated that farmers have institutional and personal sources of information about the flatbed dryer. Most respondents know about the flatbed dryer through institutional sources such as the municipal agriculturist office (MAO) of Sto. Domingo and from the office of the provincial agriculturist in Nueva Ecija, the most mentioned though was the MAO (37%). Two reasons can be attributed to this finding: (a) the provision of flatbed dryers in Sto. Domingo

Table 1. Respondents' Mode of Access to Information.

Mode of Access	Frequency	%
Pro-actively requested information	34	26
Passively received information from sources	97	74
Total	131	100

Source: The authors.

Table 2. RCS Providers Accessed by the Respondents.

RCS Providers	Frequency*	%
Institutional sources		
Municipal agriculturist office (MAO)	48	37
Office of the provincial agriculturist	1	1
Person sources		
Fellow farmers	33	25
Insecticide and fertilizer technicians	19	15
Cooperative members	16	12
Relatives	8	6
Barangay council officials	3	2
Research and training institutions		
PhilRice	6	5
PhilMech	4	3
National irrigation administration (NIA)	6	5
State universities and colleges (SUCs)		
Central Luzon State University	1	1

Source: The authors.

Note: *Multiple responses.

was a government project under the department of agriculture where most farmers learned about the technology from MAO technicians; and (b) MAO was the most accessible source to the respondents compared to other institutional sources mandated to assist farmers.

As for personal sources, a number of respondents (25%) also learned about flatbed dryers from fellow farmers. The presence of insecticide and fertilizer technicians in the study sites was also evident. According to some respondents (14%), pesticide and insecticide sales agents frequently visited their area, so they also sought information from them. It can be observed that the respondents have a variety of information sources, though in terms of frequency, they mostly interact with those physically accessible to them.

Appropriation of Flatbed Dryer

Contrary to the common notion that farmers are passive users of technology, rice farmers in this study have modified the use of a flatbed dryer to fit their conditions. They also experimented, tried out possibilities and modified its features to better appropriate the technology to their needs. They diagnose technical/mechanical problems during their use of the dryers. Those who have tried drying their *palay* in the flatbed dryer claimed that their *palay* had a smoke-like odour after being dried in the flatbed dryer. Some respondents said that their grains broke into chips when dried. To solve the problem, the operators experimented and dried only 80 cavans instead of the recommended 100 cavans capacity of the dryer (Table 3). According to the operators interviewed, drying 100 cavans per batch caused

uneven drying of *palay* while drying 80 cavans only resulted to a better quality of dried *palay*. Rice farmers also faced economic problems in using the technology due to the expensive drying fee per cavan and the cost of rice hulls for fuel. The government gave the flatbed dryers free to operators who were willing to donate a parcel of their land to where the units would be installed. The unit was given free, but users had to shoulder the expenses of drying their rice; these included rice hulls and gasoline. It is worth noting that during the peak of flatbed usage especially during typhoons, farmers experienced long waiting hours before they could dry their *palay* since there was only one flatbed dryer in the barangay. To cope with this situation, they arranged their schedule for drying the *palay* to accommodate all farmers.

Based on these problems, it can be stated that despite the shortcomings of the designed flatbed dryer, rice farmers chose to use it in unique ways. They did not remain passive recipients of the technology but rather made ways to make the technology useful in their local settings. This also implies that the success of technology cannot be measured by mere adoption, rather, it must be appropriated to its users' needs and tailored to their social and economic reality. Table 3 presents the problems encountered in column one and the appropriation strategies in column three. It is also noteworthy that the farmers' efforts in appropriating the technology led to the re-configuration of the flatbed dryer by service providers, that is, new designs were invented to address the limitations of the previous design.

Peer/Group Learning

According to FAO (2010), innovation takes place primarily in groups. The cooperative members interviewed were able to access timely and reliable information by attending cooperative assemblies. During these gatherings, their leaders shared information about the flatbed dryer. This was also a venue where they shared their knowledge and experience in using the flatbed dryer to their fellow farmers. Therefore, most of the users of the technology were cooperative members because they saw the benefit of using the flatbed dryer from their fellow cooperative members. Another opportunity for peer/group learning was through attending seminars and training. As shown in Table 4, there was a small number of rice farmers (24%) who had attended seminars and training related to the flatbed dryer. This implies that even if the MAO of Sto. Domingo and other national agencies adjacent to Sto. Domingo had been organising training and seminars all these years, but still, a large number of farmers have not maximised their benefits from learning and advancement of their rice-farming practices. The farmers mentioned that they prefer to apply their traditional farming practices. They were also passive and only wanted to be visited on their farms rather than actively attending seminars and training. For some respondents, time is essential, and they would rather spend it on their farm. In contrast, those with larger farms had attended seminars and training because they had labourers for attending their farms.

Table 3. Problems Encountered and Appropriation Strategies.

Problems Encountered	Frequency	Appropriation Strategies
Technical		
a. Quality of dried *palay*		• instead of 100 cavans, only dried 80 cavans per load
• poor/lesser quality of dried *palay*	11	
• breaks into chips	2	
• *palay* spoilage	2	
• grain discolouration	1	
• over-dried *palay*	1	
b. Machine operation		
• non-operational parts	4	• looked for suppliers from nearby provinces • improvised for non-operational parts
• power interruption	2	
• smoke-like odour	2	
• no gauge for temperature	1	
• spare parts were not readily available	1	
Economic		
• rice hull is expensive/ rice hull shortage	1	• stock rice hull before harvest season • go back to sun drying
• expensive drying cost	1	
Social		
• long waiting line/hours	1	• arranged schedule with fellow farmers

Source: The authors.

Table 4. Peer/Group Learning Activities.

Peer/Group Learning Activities	Frequency* (n = 54)	%
Cooperative assemblies	37	69
Seminar/trainings	14	24
Farmers field school	4	4
Others:		
Served as resource person in flatbed dryer operation	1	2
Invited by PhilMech in modifying flatbed dryer Design	1	2

Source: The authors.

Note: *Multiple responses.

Moreover, few of the respondents interviewed were members of farmer field schools (FFS) that met every Thursday. In the FFS, they learnt more about rice production to help them increase rice productivity. The FFS was organised by PhilRice in partnership with MAO of Sto. Domingo.

Conclusions and Policy Recommendations

RCS was being carried out to enable the farmers to use the flatbed dryers. In terms of RCS orientation, communication services were source-oriented rather than

demand-driven. Rice farmers passively received information from service providers and were not involved in the planning and implementation of communication services. Respondents learned more about the flatbed dryer through their cooperatives. For those who were not members of cooperatives, information flow usually happened with their fellow farmers and relatives. Generally, learning was more positive for farmers who were members of cooperatives because they were provided with up-to-date information, since service providers usually target farmers in formal groups. The farmers had difficulties using the technology, but they were able to overcome these obstacles by employing appropriation strategies, which resulted in peer/group learning among them. As agriculture became more knowledge-intensive, farmers needed access to timely and relevant information to increase their productivity.

A multi-stakeholder approach could be used to involve the entire community, not just the farmers. It takes a village to appropriate a technology; therefore a 'multi-stakeholder' approach can be employed to involve the entire community in appropriating a technology. As an example, the Sangguniang Barangay can serve as a partner in the information caravan or in organising other activities involving the farmers. Other organisations in the community (e.g. farmers' organisations, religious groups, women-oriented groups and socio-civic groups) can serve as partners for resource-sharing and mobilisation. Furthermore, it is recommended that rice farmers join farmers' organisations, which can help in providing access to timely and reliable information to help them in increasing their productivity. Organisations like farmers' cooperatives existing in their barangay can act as one entity, for them to be able to represent them in policy-making bodies.

For flatbed dryers or other mechanical dryers to be appropriated, they must be designed for small-scale farmers who compose the majority of Filipino farmers. As discussed in this study, small-scale farmers were not able to fully benefit from the flatbed dryers because of the need to sell their *palay* after harvesting to have money to repay debts and to spend for household needs. They opted to sun dry their harvest since this is the least expensive. It was easier for large-scale farmers to use the technology because they have more resources. Thus, RCS is important, first, by creating awareness among farmers that they may be able to improve their rice productivity by using mechanised drying because it will improve their harvest, especially during the rainy season. Second, by creating awareness, they will be able to organise themselves in that they can lobby and express their needs. Third, sharing their best practices while helping each other is also a communication process.

Additionally, to ensure that farmers are provided with agricultural technologies that they can use, they must be involved in the planning, design and implementation of agricultural innovations. Also, recipients of technologies (e.g. cooperatives) should be provided first with capacity-building assistance and strengthened financial services so that they can undertake programs and activities necessary for technology appropriation. Similarly, the enactment of appropriate legislation will help farmers' organisations operate and manage themselves.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding

The authors disclosed the receipt of the financial support for the research, authorship and/or publication of this article: This work was supported by the Philippine's Commission on Higher Education (CHED) through the Faculty Development Program Scholarship. The authors greatly acknowledge the funding support given by CHED.

References

Craig, R. (1999). Communication theory as a field. *Communication Theory Nine: Two May*, 119–161.

Craig, R., & Muller, K. (1999). *Theorizing communication, reading across tradition*. SAGE Publications.

Food and Agricultural Organization. (2010). *Advancing adaptation through communication for development*. Proceedings of the technical session on Communication. Third International Workshop on Community-based Adaptation to Climate Change February 2009 Dhaka, Bangladesh. FAO: Rome, Italy.

Food and Agricultural Organization. (2014). *Farming for the future. Communication efforts to advance family farming*. FAO.

Food and Agricultural Organization. (2017). *Inclusive rural communication services building evidence, informing policy*. FAO.

Janneck, M. (2009). *Recontextualising technology in appropriation processes handbook of research on socio-technical design and social networking systems*. IGI Global.

Paddy Drying. (2013). *Training manual, 2013*. International Rice Research Institute. https://documents.pub/document/paddy-drying-training-manual.html

Wirth, W., Karnowski, V., & Pape, T.von. (2006). An integrative model of mobile phone appropriation. *Journal of Computer-Mediated Communication*, *13*(3), 593–617. https://www.researchgate.net/publication/257150365

A Case Study: Explaining the Price Collapse of Tongan Squash Export to Japan

Asia-Pacific Journal of Rural Development
32(1) 64–72, 2022

DOI: 10.1177/10185291221117375
journals.sagepub.com/home/jrd
SAGE

Noriyuki Segawa[1]

Abstract

This article focuses on the squash industry of Tonga, which was successfully developed in the 1990s and declined in the 2000s. It analyses how squash export prices are affected by the quantity of squash export and the number of squash exporters. An examination of the squash industry demonstrates that the collapse of the export prices and the decline of the industry is caused due to the lack of structural frameworks for managing the industry effectively and/or the functional failure of the framework. It is perceived that the decline of the industry was due to the withdrawal of the squash export quota from the government, but the main factor appears to be the failure of the government to control the quality of the squash exported to Japan. Thus, a weak institutional capacity prevented the sustainable development of the industry. This article concludes that the development of institutional and human capacity to establish structural frameworks for managing industries and operating the frameworks effectively will contribute to the sustainable development of an export-oriented agriculture-based industry in the PICs.

Keywords

Pacific Island countries (PICs), Tongan Squash Industry, export quota, quality control, institutional capacity

Introduction

The growth rate of gross domestic product (GDP) of Pacific Island countries (PICs) ranged from approximately 1.5% to 2.5% from 2001 to 2017 (Asian

[1] Faculty of International Studies, Kindai University, Osaka, Japan

Corresponding author:
Noriyuki Segawa, Faculty of International Studies, Kindai University, 3-4-1 Kowakae, Higashiosaka, Osaka 577-8502, Japan.
E-mail: segawa@intl.kindai.ac.jp

Development Bank, 2019). Fiji recorded a 2.4% annual growth rate of GDP, and PNG had a 5.9% growth rate, while the annual growth rate of GDP of the other PICs was lower. According to the Japan Economic Research Institute (2016, p. 2), only Fiji and PNG can achieve economic growth and economic self-reliance, while Hezel (2012, p. 26) argued that except for Fiji, PNG, the Solomon Islands and possibly Vanuatu, PICs cannot develop resources or products. PICs have aimed to promote industrial development and achieve economic self-reliance since their independence. These goals have not been achieved yet mainly due to their geographical disadvantages, such as small land area and population, scattered islands and population, frequent natural disasters and remoteness.

Their geographical disadvantages make the production of a commodity in huge volumes difficult and unstable. Often production in a larger volume lowers the production cost of a commodity, which enhances the chance of exporting that commodity abroad. Even when there is a low-cost commodity with high export potential the geographical disadvantages of PICs make them unsustainable. Since PICs are far away from major markets, their export industries face problems with a proportionately high level of transportation costs. Both local and foreign investors look for some comparative advantage when they invest in targeting export-oriented products. A high transportation cost is a natural barrier to such an advantage. Still, local entrepreneurs produce commodities focusing on the demand of the local markets, but foreign investors remain reluctant in such a case. This reluctance on the part of the foreign investors makes the foreign direct investment (FDI) inflow small.

Table 1 shows that small PICs (not including Fiji and Papua New Guinea, PNG) have received only a small amount of FDI, which is essential for developing countries to improve their economic performance. A comparison of small Caribbean Island countries demonstrates that the amount of FDI inflow to PICs is particularly small. For example, over the period of 2000–2019, the average annual FDI inflows to the Dominican Republic, with a population of approximately 72,000, Antigua and Barbuda, with a population of approximately 97,000 and Barbados, with a population of approximately 287,000, were US dollars 25.7, 136.3 and 358.3 million, respectively.[1] This information indicates the difficulty that small PICs, far from major markets, face in developing their industries and economies.

It has been difficult for PICs, except Fiji and PNG, to find potential export industries and develop them. However, a few industries in these countries have successfully developed in the past and at present. Indeed, in Fiji, the garment industry expanded in the late 1980s and early 1990s and the export of bottled water has developed, and in PNG, the export of liquified natural gas has driven the economy. Tonga succeeded in developing the squash industry. This industry was a significant driver of its economic development in the late 1990s and early 2000s; however, the industry has declined since 2006. This indicates that the development of export industries is not impossible for PICs with geographical disadvantages.[2]

However, the sustainable development of these industries is a key challenge for these countries. The question is why did the squash industry of Tonga decline?

Table 1. Average Annual Inflow of FDI over 2000–2019 and Population.

	Fiji	PNG	Palau	Marshall	Solomon	Vanuatu	Tonga	Samoa
Annual FDI inflow (mil. US$)	282.1	158.4	14.8	4.8	39.9	35.0	6.9	10.8
Population (thousand)	850	7,000	20	55	535	240	100	180

Source: Retrieved October 10, 2020, from https://data.worldbank.org/indicator/BX.KLT.DINV.CD.WD.

The examination of this industry can provide insights as to how PICs with geographical disadvantages can develop export industries, maintain their sustainability and consequently help in achieving economic self-reliance for them. This examination will provide a lesson with regard to what is necessary for sustainable industrial development in agriculture. One of the key factors for PICs not to achieve sustainable industrial development, especially in an export-oriented agriculture-based industry, will be analysed in this article by examining the development and decline of the squash industry in Tonga. It will show that it is not the withdrawal of the export quota on Tongan export to the Japanese market but rather the decline of the quality of squash exported to Japan that brought the decline in the export prices and volumes of Tongan squash in Japan.

The Price Collapse of Tongan Squash Export to Japan

In 1987, Tonga started producing squash mainly for export to Japan. In the peak period from 1999 to 2003, more than 17,000 tons, on average, were exported annually to Japan (Figure 1). The area for squash cultivation also increased from 81 hectares in 1987 to 2,114 hectares in 1994 and 4,408 hectares in 2000 (van der Velde et al., 2007, p. 459). During this period, squash exports constituted approximately 40%–45% of the total exports (van der Velde et al., 2007, p. 459). This increase in the value of exports was reflected in the number of people participating in the squash industry; the number of squash farmers increased from approximately 40 in 1987 to 2,000 in the late 1990s value (Felemi, 2001, p. 32), while the number of squash exporters increased from 2 in 1989 to 15 in 2004 (Nishi Trading, 2013). During the peak period, approximately 15% to 20% of the working population participated in the squash industry (Chand & Naidu, 2010, p.139). However, the squash industry has declined since 2006, with only 1,000 tons exported in 2008 (Figure 1).

In 1991, the Ministry of Labour, Commerce, and Industries (MLCI) in Tonga implemented a quota system for squash exports to avoid oversupply in the Japanese market. Japanese companies complained that Tongan exporters did not respect trade negotiations (van der Velde et al., 2007, p. 60) and that the Japanese market was flooded with Tongan squash (Van der Grijp, 1997, p. 34). It was

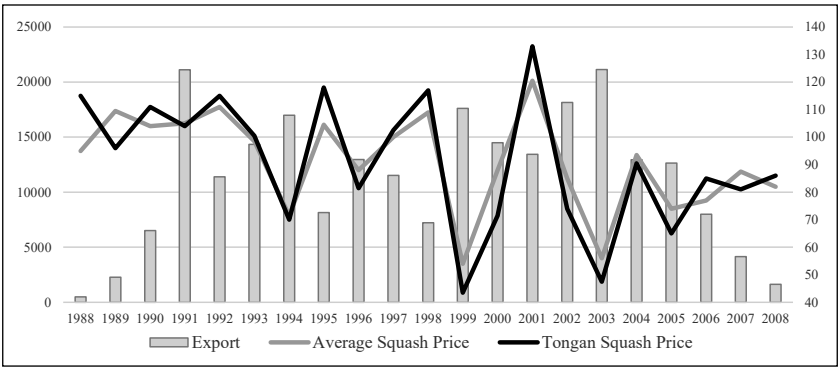

Figure 1. Amount of Squash Exports and Export Prices.

Source: Agriculture and Livestock Industries Corporation (n.d.).

important for the sustainable export of the industry to comply with the request of Japanese importers regarding the export volume, since trade in commercial crops is generally buyer-driven, with buyers usually having absolute power in the supply chain which is known as monopsonistic competition in the terminology of economics. The introduction of the quota system was expected to stabilise the squash export price and improve the quality of squash. The MLCI set a total export volume of 10,000 tons in 1991 and 1992 and 13,000 tons in 1993 (Van der Grijp, 1997, p. 35). However, the squash export was much more than the export quota set by the government, with approximately 21,000 tons in 1991, 11,500 tons in 1992 and 14,500 tons in 1993 (Figure 1).

In response to the non-compliance with the government quota, the government passed a law in November 1993 to prevent exporters from exporting more than the quota. After the implementation of the law, exporters adhered to the government quota. The total volume of quota was 17,000 tons (including 2,000 tons as reserve) in 1994 and 15,000 tons in 1995 (Van der Grijp, 1997, pp. 33–35), while the export amount was 17,000 tons in 1994 and due to drought, Tonga could export only 8,100 tons in 1995 (Figure 1).

In March 1994, six out of seven exporters asked the government to abolish the quota system. They claimed that the government intervention had to be minimised, free markets had to be allowed as in other countries (Tonga Chronicle 1994[3] cited in Van der Grijp, 1997, p. 47) and the quota system caused fierce competition among the exporters of Tonga (Chand & Naidu, 2010, p.153; Felemi, 2001, p.14). However, the government refused their call. The MLCI reiterated that, without the quota, the resultant over-export would bring in a negative effect through, for example, complaints from Japanese importers, quality loss and export price collapse. The Tonga Development Bank indicated that the elimination of the quota system would lead to a reduction in the income of exporters and farmers and that their debts would increase (Tonga Chronicle 1995[4] cited in Van der Grijp,

1997, p. 47). However, due to the repeated demands by exporters, the cabinet finally decided to abolish the quota system in 1996. This means that after 1996, the exporters instead of the government were required to manage the industry to avoid problems of overproduction and excessive export.

Consequently, the exports to Japan increased gradually. Between 1999 and 2003, more than 17,000 tons were exported annually on average. This amount surpassed the export demand in Japan leading to a reduction in the squash export price, as the government had anticipated during the imposition of the quota. In the period during which the quota system and law were implemented and overproduction and export were avoided, the stability of the Tongan squash export price was protected to some extent and the exporters often succeeded in obtaining a high price from Japan (Figure 1).

The average squash import price per kilogram in the Japanese wholesale market was Japanese Yen (JPY) 71.5 in 1994 and JPY 104.5 in 1995, while the import price of Tongan squash in the market was JPY 70.0 in 1994 and JPY 118.0 in 1995.[5] After the abolishment of the quota system, the Tongan squash export price generally collapsed (Figure 1 and Table 2). The average squash import price per kilogram was JPY 54.0 in 1999 and JPY 88.0 in 2000, while the import price of Tongan squash was JPY 43.5 in 1999 and JPY 71.5 in 2000.[6] Additionally, after the abolition of the quota system, the import price of Tongan squash was much lower than its average price during the period with a large volume of exports, especially in 1999, 2002 and 2003. In 1994, before its abolition and with 17,000 tons of exports, the import price of Tongan squash was maintained almost the same as the average import price of squash.

It is natural that when the export of a certain commodity or produce becomes highly profitable then many entrepreneurs will try to engage in the export business and there is nothing wrong with it. Obviously, the greater the number of exporters the higher will be competition among the exporters. This will drive down the profit margins, but there should be an expansion in the production and export of squash. If a large number of exporters drive down the profit margins to zero or negative, then some of the exporters will go out of business and a normal profit margin is expected to be established with a lower volume of export. Overall, the profit margin depends on the diversity of export markets and the relative bargaining power of the importers and exporters. But it is difficult for the PICs to diversify their exports due to their geographical disadvantages. Therefore, the government regulation of the export volume through different measures becomes important.

Table 2. Comparison of Import Prices of Squash across Regimes.

	During Quota		During No Quota	
Import Price in JPY	1994	1995	1999	2000
Average import price of Japan	71.5	104.5	54.0	88.0
Import price for Tongan squash	70	118.0	43.5	71.5

Source: Agriculture and Livestock Industries Corporation (n.d.).

If due to intense competition among exporters in Tonga, as claimed by many, there is a fall in the export prices of squash from Tonga; there should have been an expansion in Tongan export to Japan. Basic economic theory tells this. However, if Japanese import from other countries becomes even cheaper than the Tongan squash then the decline in Tongan export to Japan may make sense. In fact, the average import price of squash in Japan was higher than that of Tonga (Table 2). Rather import volume from other than Tonga is expected to decline than the import from Tonga is expected to increase. Export Quota gives advantages to the exporters who get licenses, but it is not necessarily an export earning maximiser. Rather the withdrawal of quota maximises export earnings through lower prices coupled with a relatively larger volume of export. But it did not happen. Why? Maybe the quality of squash declined in the case of Tonga due to that 'unhealthy' competition among Tongan exporters. Therefore, the decline of the industry appears not to be because of lifting quota restrictions but rather the failure of the government to strictly maintain the quality of the squash produced for the Japanese market.

Substandard Quality and the Price Collapse

The number of squash farmers increased from approximately 40 in 1987 (Felemi, 2001, p. 32) to 1,000 in 1992, 1,500 in 1995 (Nishi Trading, 2013) and 2,000 in the late 1990s (Felemi, 2001, p. 6), while the number of squash exporters also increased from 2 in 1989 to 8 in 1991, 13 in 1994 (Felemi, 2001, p. 10) and 15 in 2004 (Nishi Trading, 2013). This trend indicates that the number of farmers and exporters was not controlled. Well, this is supposed to corner exporters from other countries and thus realise higher export volume for Tongan squash albeit at lower prices. But the price collapse did not come with a higher volume of Tongan squash export. Some exporters asked the government to control the number of exporters, claiming that the squash market in Tonga was flooded and that some exporters shipped out disqualified products such as undersized and discoloured squash, which would lead to a loss of trust among Japanese importers and consequently cause the collapse of the industry through lower demand for squash from Tonga (Van der Grijp, 1997, p. 34). The claim of exporting substandard, that is, undersized and discoloured squash, is the main culprit to be responsible for the collapse.

In 1992, the MLCI set the criteria for approving export licenses, with the purpose of guaranteeing the quality of squash in export markets. As a result, the government gave licenses to only 7 companies among 22 applicants in 1992 (Tonga Chronicle 1992[7] cited in Van der Grijp, 1997, p. 34). Moreover, the government set a tighter criterion in 1997 because 13 companies met the criteria and obtained the license in 1994 and 1996 (Felemi, 2001, p. 10). Doing so contributed to a reduction in the number of exporters, with 8 in 1997 and 7 in 1998 (Felemi, 2001, p.10). However, the government regulation gradually lost its

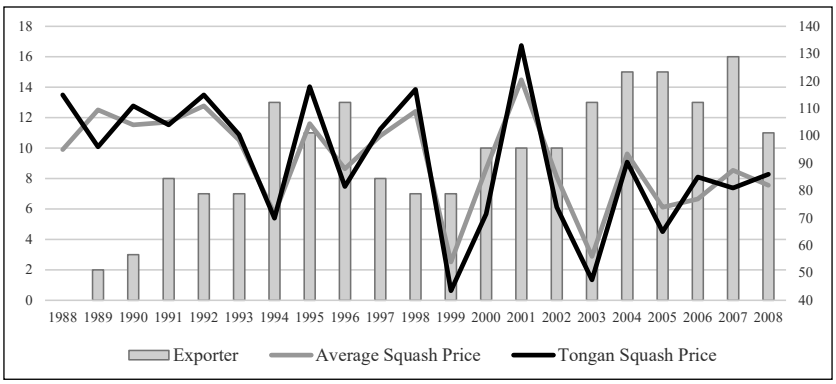

Figure 2. Number of Squash Exporters and Export Prices.

Source: Nishi Trading (2013); Felemi (2001); Agriculture and Livestock Industries Corporation (n.d.).

relevance in controlling the number of export companies, as the number of exporters increased again to 10 in 2000 and 15 in 2004.

The surge in export companies not only caused the export of substandard products but also allowed Japanese importers to negotiate the import prices of squash, pitting one exporter against another (Chand & Naidu, 2010, p.152). This negotiation intensified due to the domestic competition over the export price among the exporters[8] and resulted in the collapse of the export price leading to the loss of the profit margin in the end. In the period with an excessive number of exporters, the import price of Tongan squash per kilogram in the Japanese wholesale market was driven down to JPY 81.5 in 1996 and JPY 65.0 in 2005, whereas the average squash import price in the market was JPY 88.0 in 1996 and JPY 74.0 in 2005[9] (Figure 2). In 1992, 1993, 1997 and 1998, when the number of exporters was small, the import price of Tongan squash was higher than the average import price in the Japanese market (Figure 2). Maybe, it is easier for the government to control the quality of a product when there are fewer exporters in the market. Therefore, the blame goes on to the failure of quality control rather than the control of the number of exporters.

One interesting point to note is that there was the stability of Japanese demand for squash in general even though there was a significant decrease in the import prices of squash from Tonga. This has resulted partly from the fact that there is monopsonistic competition in the Tongan squash market in Japan, which has resulted from the higher bargaining power of the few Japanese buyers/importers. Had there been alternative export markets for Tongan squash other than Japan, the results would have been different. The 'unhealthy' competition through lowering the quality of the squash would not have happened, had there been many other export destinations for Tongan squash. Therefore, this is also a problem of a non-diversified export market for Tongan squash resulting from PICs geographical disadvantages.

Conclusion

PICs have aimed to develop export industries and achieve economic upliftment. These goals have not yet been achieved mainly because of PICs' geographical disadvantages. It is important to consider how PICs can develop their export industries and support their sustainability despite the geographical disadvantages. This article focuses on the squash industry of Tonga which was successfully developed in the 1990s and declined in the 2000s. The examination of the squash industry in Tonga demonstrates that overproduction and export from Tonga to Japan and intense competition from exporters caused the collapse of the export price. It can be expected that the cheaper import price of Tongan squash than the average import price in the Japanese market contributes to the increasing volume of Tongan squash export to Japan. However, the squash industry in Tonga declined with a lower volume of squash export to Japan. This is because the decline in the quality of Tongan squash resulted from the 'unhealthy' competition among the Tongan exporters.

Due to its geographical disadvantages, export industries in Tonga have faced problems with a proportionately high level of transportation costs. Intense competition among the competing exporters further erases profit margin in export industries, which is relatively small. As a result, the drop in the profit margin caused quality loss with 'unhealthy' competition among the exporters resulting in the loss of trust among Japanese importers. Due to the lack of trust in the quality of Tongan squash, export volumes of Tongan squash declined despite its relatively lower prices of them.

Had there been alternative export markets for Tongan squash other than Japan, the results would have been different. However, it is difficult for the PICs to diversify their export markets due to their geographical disadvantages. Therefore, the government regulation of the export volume and exporters number was important. However, it faced the lack of structural frameworks for managing the industry effectively and/or the functional failure of the framework. Towards the sustainable development of an export-oriented agriculture-based industry, it is significant for the PICs with the geographical advantages to develop institutional and human capacity leading to the establishment of structural frameworks for managing industries and their effective operation.

Notes

1. World Bank (n.d.). Retrieved October 10, 2020, from https://data.worldbank.org/indicator/BX.KLT.DINV.CD.WD
2. It is significant to examine what could offset the negative effects of geographical disadvantages on the development of export industries in small PICs. The Pacific Island Centre (2013) examined this question in agriculture, tourism, manufacturing and service industries.
3. Free Market System Considered from Pumpkin Export, *Tonga Chronicle* (24 March 1994).
4. Pumpkin Report Urges Retention of Export Quotas, *Tonga Chronicle* (21 December 1995).
5. Data from Agriculture and Livestock Industries Corporation (n.d.).

6. Data from Agriculture and Livestock Industries Corporation (n.d.).
7. Pumpkin Exporters Make Allocations, Agree to Co-operate, *Tonga Chronicle* (12 March 1992).
8. It is natural that when the export of a certain commodity or product becomes highly profitable then many entrepreneurs try to engage in the export business and there is nothing wrong with it. Obviously, the greater the number of exporters the higher will be competition among the exporters.
9. Data from Agriculture and Livestock Industries Corporation (n.d.).

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding

The author received no financial support for the research, authorship and/or publication of this article.

References

Agriculture and Livestock Industries Corporation. (n.d.). *Vegetable total and aggregate information network*. Retrieved March 27, 2020, from https://vegetan.alic.go.jp

Asian Development Bank. (2019). *Key indicators for Asia and the Pacific 2019*. https://www.adb.org/publications/key-indicators-asia-and-pacific-2019

Chand, A., & Naidu, S. (2010). Economic contribution and analysis of supply chain of Tongan squash pumpkin industry. *Asian Journal of Management Research*, *1*(1), 139–156.

Felemi, M. (2001, September 18–20). *Constraints, challenges and prospects for development of the squash export industry in Tonga* [Paper presentation]. The Regional Workshop on the Constraints, Challenges, and Prospects for Commodity-Based Development, Diversification, and Trade in the Pacific Island Economies, Nadi Fiji.

Hezel, F. X. (2012). *Pacific Island Nations: How viable are their economies?* Honolulu, East-West Center.

Japan Economic Research Institute. (2016). *Evaluation of Japan's assistance for Pacific Island countries: Third party evaluation report 2015, Ministry of Foreign Affairs*. https://www.mofa.go.jp/policy/oda/evaluation/FY2015/pdfs/pacific_island.pdf

Nishi Trading. (2013, February 20). *Contribution and challenges of squash export and its contribution to the economy* [PowerPoint presentation]. Ministry of Agriculture, Food, Forests and Fisheries Annual Conference 2013, Tongatapu.

Pacific Island Centre. (2013). *The Pacific Islands' challenges: Perspectives of economic development in the Small Island States*.

Van der Grijp, P. (1997). Leaders in squash export: Entrepreneurship and the introduction of a new cash in Tonga. *Pacific Studies*, *20*(1), 29–62.

van der Velde, M., Green, S., Vanclooster, M., & Clothier, B. E. (2007). Sustainable development in small island developing states: Agricultural intensification, economic development, and freshwater resources management on the coral atoll of Tongatapu. *Ecological Economics*, *61*(2–3), 456–468.

World Bank. (n.d.). *Foreign direct investment, net inflows*. Retrieved October 10, 2020, from https://data.worldbank.org/indicator/BX.KLT.DINV.CD.WD

Field Note

Determinants of NPLs of Self-Help Group-Bank Linkage Program in India: Empirical Evidences and Policy Implications

Asia-Pacific Journal of Rural Development
32(1) 73–92, 2022

DOI: 10.1177/10185291221114682
journals.sagepub.com/home/jrd
SAGE

M. Srikanth[1], Lagesh M. A.[2] and Mohammed Kasim C.[3]

Abstract

This article examines the major factors influencing the non-performing loans (NPLs) of the Self-Help Group-Bank Linkage Program (SHG-BLP) in India at both macro- and micro-levels. A panel regression analysis of the state-level data shows that the total outstanding loan amount, average loan size per SHG and poverty rate exert positive impacts, whereas gross state domestic product has a negative effect on gross non-performing loans (GNPLs). Analysis of primary data indicated a higher incidence of loan default by SHG members. Logit regression analysis employed on primary data suggests that the loan default by SHG members is positively associated with age and experience because of higher family responsibility and lesser incentive to repay the loan. On the other hand, self-employment, levels of income and savings show negative relations with loan default. Self-employed SHG members and those who make some savings are less likely to default on loans. Similarly, higher-income groups show less chance to default on loans. An analysis of the perceptions of the SHG members reveals that poor economic conditions, non-cooperation among members, social and medical expenses, and expectations of loan waiver from the government are the main reasons for loan defaults.

Keywords

Self-Help Group-Bank Linkage Program, determinants of NPL, bad loans, logit regression, India

[1] Centre for Entrepreneurship Development & Financial Inclusion (CEDFI), National Institute of Rural Development & Panchayati Raj, Ministry of Rural Development, Rajendra Nagar, Hyderabad, Telangana, India
[2] Department of Economics, ICFAI Business School (IBS), Hyderabad, Telangana, India
[3] Department of Economics, Farook College, Kozhikode, Kerala, India

Corresponding author:
Mohammed Kasim C., Department of Economics, Farook College, Kozhikode, Kerala 673632, India.
E-mail: kasimeco@gmail.com

Introduction

Self-Help Group-Bank Linkage Program (henceforth SHG-BLP) is a landmark model initiated by the National Bank for Agriculture and Rural Development (NABARD) in 1992 to deliver affordable doorstep banking services in the realm of financial inclusion in India. It has been a home-grown self-help movement with an aim of creating sustainable livelihood opportunities for the rural poor (Srikanth & Reddy, 2017). Even though it was started as a bank outreach program, SHG-BLP transcended itself into a holistic development model for building social, economic, human, and of late, technological capital in rural India (NABARD, 2018a, b). SHG-BLP is widely recognised as the largest microfinance program in the world in terms of outreach (Harper, 2002; Mohapatra, 2016). By now it is widely accepted that microfinance has significantly contributed to the rural transformation in India through its several channels. It has succeeded in mobilising small savings at a lower cost from less-educated rural poor who were not part of the formal banking system (Oommen, 2018; Srinivasan, 2008). Further, it provided micro-credit to poor families without collateral, which in turn helped them to venture into new means of livelihood and also to overcome short-term financial crises. Thus, the ease of access to credit has made the livelihoods of rural poor more sustainable. More importantly, microfinance helped the ultra-poor to meet their most basic needs and also protected them against livelihood risks (Banerjee & Duflo, 2011).

Similarly, it is believed that SHG-BLP contributed to the empowerment of women through their control over financial resources and their role in decision-making (Hundekar & Munshi, 2020; Sundaram, 2012). There is also evidence of the SHG-BLP's contribution to the improvement of financial inclusion (Ramanathan, 2007) and the reduction of poverty especially when the households are part of female SHGs (Sinha et al., 2012). Self-Help Groups are community-based organisations and act like Thrift and Credit Societies (TCSs) by mobilising savings from members and depositing them into banks, which are later used to provide them loans for the establishment of micro/small enterprises. Therefore, the benefits of SHGs include mobilisation of savings and credit facilities and pursuit of group enterprise activities (Anand, 2002). The entire process of financial management of SHGs is carried out by the elected women representatives. SHGs also create a social space for women to discuss their concerns and opportunities that considerably improve their confidence and self-esteem (Al-Kubati & Selvaratnam, 2021; Rajeev et al., 2020). Further, SHGs are integrated with the local governments and hence they act as agents of social and economic change by implementing several development programs (Gupta et al., 2020).

SHGs do face certain challenges that are inevitable given the socio-economic constraints in the rural areas of India. After obtaining microfinance, an SHG generally takes three to five years to mature and reach the stage of self-sustainability—graduating from consumption and or low productive activities to economic enterprises (Deshpande et al., 2016; Reji, 2010; Subrahmanyam, 2009). However, most of the SHG members may not undertake entrepreneurship due to a lack of required management skills, technical know-how, and value addition for

their products and also because of the absence of market linkages, conducive government policy, etc. (Kumar, 2016; Mani, 2015). Another challenge is the low level of financial literacy of the SHG members in rural areas. Only 11% of the rural population has good financial literacy against 15% in semi-urban areas (NABARD, 2018a, b). As a result, most of the loans are availed by the financially savvy members (namely the president, secretary and treasurer) in the group without recourse to the rotation of leadership (Raj, 2012). Consequently, the SHG-BLP accumulated bad loans in certain pockets of the country due to the dominance of key members and consequent non-cooperation among the group members. Such a problem was also observed during the primary survey of the study (NIRDPR, 2019).

Despite the remarkable achievements of SHG-BLP such as poverty alleviation and empowerment of women, mounting gross non-performing loans (GNPLs) over the years remains a serious policy challenge in India. Though the SHG-BLP was intended as a 'low non-performing loan (NPL) movement', bad loans had been increasing in the recent past due to various reasons. Total NPLs of SHG-BLP in India increased from ₹423 crores in 2007–08 to ₹4,628 crores in 2017–18. In Andhra Pradesh (AP) bad loans increased partly due to the microfinance crisis (undivided state) during 2009–10 (Raj, 2012); and partly because of the subsidy component through Swarnajayanti Gram Swarozagar Yojana (SGSY) (Karmakar, 2009) and expectations of loan waivers from the government. Besides, when the bank loan availed by the SHG member is insufficient to start an economic activity, the underfinanced loan amount might be diverted towards consumption purposes and thus turned out to be an NPL (Sukanya, 2017). Though the NPLs of the SHG-BLP stood at 1.36% of the total amount of outstanding loans in the FY 2005–06 for entire India, gradually they peaked at a record high of 7.40% in the FY 2014–15 and later declined to 6.12% as on March 31, 2018. Higher NPLs may ultimately result in the creation of structural barriers regarding rural credit in general, and sustainability of the SHG-BLP in particular. Specifically, bank officials may be reluctant to grant further loans in case of rising defaults from the SHG members. Besides, the financial position of banks and financial institutions will be in jeopardy in view of a higher incidence of bad loans.

Against the backdrop of this emerging crisis in the microfinance sector, this article tries to address an important research question, that is, what are the factors causing the high NPLs in the SHG-BLP? In the existing literature, most of the international studies focused MFIs and not many studies are carried out on the SHG-BLP program. A number of international studies have examined the factors influencing the loan defaults by the members of MFIs and found that loan size, educational status, end-use of loans, number and age of members of a group, interest rate and loan monitoring are the major determinants (Aidoo & Mensah, 2018; Chikalipah, 2018; Gutu et al., 2017; Nawai & Shariff, 2012). In the Indian context, most of the studies on the SHG-BLP program have evaluated the performance and sustainability of SHG-BLP program (Aluni & Ray, 2015; Mahapatra & Dutta, 2016; Parida & Sinha, 2010; Puhazhendi & Badatya, 2002; Srinivasan, 2008). The studies that examined the determinants of NPLs of SHG-BLP are few in India and further, they are regional studies covering a state or a specific region.

Thus, the main contribution of this study is that we have examined the research question at both the macro-level and micro-level. Therefore, our objective in this article is two-fold: First, we make a macro-level analysis of determinants of gross GNPLs in the SHG-BLP by applying a panel regression model on the data from 28 states for a period of 10 years. Such comprehensive panel data analysis, by capturing both temporal and cross-section dimensions in the data would clearly suggest the major macroeconomic variables influencing the level of GNPLs in the SHG-BLP in various states. Second, we examine the primary data collected through a sample survey from three regions of India to understand the incidence, reasons and determinants of loan defaults among SHG members.

Data and Methodology

Estimation Method

We investigate the macroeconomic determinants of gross GNPLs in the SHG-BLPs in India. This was achieved using the state-level information covering a cross-section of 28 states in India and for a period of 10 years, that is, from 2008 to 2017. Considering the nature of the dataset, we apply a panel regression model that would capture both temporal and cross-sectional dimensions. The data required for the macroeconomic analysis have been collated from various reports of NABARD and NSSO and the handbooks of the Reserve Bank of India.

While the dependent variable is GNPLs of the SHG-BLP of the states, independent variables are savings of SHGs, outstanding loans of SHGs and average loan size per SHG. Poverty rate, literacy rate and gross state domestic product are taken as control variables in the model. The econometric specification of the panel regression model used in the study takes the following form:

$$\begin{aligned} \mathrm{LGNPL}_{it} = {} & \beta_0 + \beta_1 \mathrm{LTOL}_{it} + \beta_2 \mathrm{LSVD}_{it} + \beta_3 \mathrm{LAVLS}_{it} + \beta_4 \mathrm{PVRTY}_{it} \\ & + \beta_5 \mathrm{LITR}_{it} + \beta_6 \mathrm{LGSDP}_{it} + u_{it} \end{aligned} \tag{1}$$

In the model, subscript *i* and *t* denote 'state' and 'year', respectively. The dependent variable LGNPL is the logarithmic value of GNPLs of SHG-BLP.[1] Among the independent variables, LTOL is the logarithmic value of Total Outstanding Loan amount in the SHG-BLP, LSVD is the logarithmic value of saving deposits of SHGs, LAVLS is the logarithmic value of average loan size per SHG, PVRTY interpolated as poverty rate (Tendulkar Methodology), LITR is the literacy rate and LGSDP is the gross state domestic product.[2] u_{it} is the stochastic error term.

Sample Selection

As a part of the study, we collected primary data from members of the SHGs through an interview schedule. We conducted the field survey in the three sample states, namely AP, Odisha and Madhya Pradesh (MP), each of them representing

regions with various levels of NPL. While AP represents the Southern region with the low level of NPLs in India, Odisha represents the Eastern region with the medium level of NPLs and MP represents the central region with the high level of NPLs. From each sample state, later we selected two districts randomly, one district belonging to the backward region and the other district belonging to the forward region. From AP, we selected Kurnool district as the backward region and West Godavari district as the forward region. From MP, we selected Alirajpur district, a tribal-dominated area as the backward region, and Sehore district as the forward region. Similarly, from Odisha, we selected Kalahandi district, a tribal-dominated area, as the backward region, and Jagatsinghpur district as the forward region.

From these 6 districts, we chose 12 blocks (2 blocks from each district) for conducting the field survey. Subsequently, we selected one gram panchayat from each block. From each gram panchayat, 18 SHGs were selected making the total number of SHGs studied 216. Finally, we interviewed 3–4 members from each SHG, and therefore the final sample size happened to be 663 women SHG members: 189 are from AP, 263 are from Odisha and 211 are from MP. The fieldwork was conducted between March and August 2018. While identifying the sample panchayats, we selected only those panchayats which had more than 10 SHGs. Besides, we documented the perceptions of 58 stakeholders, namely bankers, office bearers of NGOs and respective government department officials. We collected primary data only from women SHGs in our survey, as we hardly found SHGs having male members. The schedule for the SHG members was prepared after conducting a pilot study in the Allagadda and Owk blocks of Kurnool district, AP. This was supplemented by focus group discussions (FGDs) to evaluate the performance of SHG-BLP with special reference to its NPLs.

Logit Regression Analysis

We address the following second question of the study using a logit regression model: What are all the factors influencing the probability of an SHG-BLP member to default on the loan availed from banks? The logit regression model is one of the widely used methods to understand the loan default probability of an individual or an entity (Peng et al., 2002). This method is apt to the present situation as the dependent variable of the current model is SHG-BLP member defaults on repayment of a loan. The theoretical specification of the Logit regression model takes place as follows:

$$\text{logit}(P(Y=1) = \log\left(\frac{P(Y=1)}{1-P(Y=1)}\right) = \beta_0 + \beta_1 X \tag{2}$$

where β_0 is the intercept of Y, and β_1 is the regression coefficient. The values of the intercept and regression coefficient are determined by the maximum likelihood (ML) method.

The logit regression specification for the present study takes the following form:

$$Y_i = \beta_0 + \beta_1 * age + \beta_2 * edu + \beta_3 * inc + \beta_4 * occu + \beta_5 * yshg + \beta_6 * noloan + \beta_7 * saving + \varepsilon, \quad (3)$$

where Y_i stands for the dependent variable, it takes the value of '1' if the SHG-BLP member defaults on repayment of the loan and '0' otherwise. Basic demographic and economic characteristics of an SHG member are taken as explanatory variables, among them *age* represents the age of SHG-BLP member; *edu* is the education level of SHG-BLP member; *inc* is the total income of an SHG member; *occu* is the occupation of the respondent; *yshg* represents the number of years of membership with SHG-BLP; *noloan* indicates the number of loans taken by the member; *saving* is the amount of savings of respondents after joining the SHG-BLP. In the model, β_0 is constant, β_i represents the coefficient of the explanatory variable and $\in$ is an error term.

Results and Discussions

Trends and Determinants of NPLs in the SHG-BLP at the Macro-Level

Microfinance in India is available mainly in two channels viz. (a) Microfinance Institution (MFI) Bank Model, and (b) SHG-BLP. Besides, microfinance is available through trusts and societies, whose share is negligible. Primarily, MFIs were inspired by the Grameen Bank in Bangladesh and the innovations based in Latin America. Out of these channels, SHG-BLP has become more popular in India than elsewhere in the world primarily due to its widespread adoption by Scheduled Commercial Banks, Regional Rural Banks and Cooperative Banks (Singh, 2008). Till March 31, 2018, the SHG-BLP trod many milestones with a total membership of 87.44 lakh groups (covering nearly 11 crore households) across India. The SHGs mobilised total deposits of ₹19,592 crores from its members as of 31 March 2018.

The SHG-BLP has marked considerable progress over the years in terms of small savings mobilised from members and the number and amount of loans disbursed (Table 1). While the number of SHGs with savings linkage increased from 50.10 lakh to 87.44 lakh, savings amount increased by ₹15,807 crores at an impressive annual growth rate of 17.9% between 2007–08 and 2017–18. Besides, the ratio of savings amount to the outstanding loan amount of SHGs improved from 0.22 times to 0.26 times during the same period. This is quite encouraging since savings form part of collateral to bank loans extended to the SHG members. Similarly, there was an increasing trend in respect of the number of SHGs availing of loans during the same period. As a result, the total amount of outstanding loans increased from ₹17,001 crores in 2007–08 to ₹75,598 crores in 2017–18. The ratio of loan outstanding to loan disbursement indicates the repaying capacity of the SHG borrowers, the higher the ratio is lower the repaying capacity. This ratio, as reported in Table 1, though declined from 1.92 in 2007–08 to 1.53 in 2015–16,

remains high at 1.60 in 2017–18. Therefore, high outstanding loan amount coupled with low disbursement amount reflects a low repayment rate of SHGs as they are not eligible for fresh loans on account of overdue. Consequently, the amount of GNPLs in absolute volume experienced massive growth from ₹423 crore in 2007–08 to ₹4,628 crore in 2017–18. As a percentage of the total loan outstanding, GNPLs increased from 2.49% to 6.12% during the same period.

As such, the increasing trend of GNPLs has triggered a debate about the sustainability of the SHG-BLP. In this context, it is important to address the major factors driving the GNPLs in SHG-BLP. Firstly, let us discuss the state-level macroeconomic variables influencing the amount of GNPLs in SHG-BLP with the help of the results of the panel regression model (Table 2). We have performed a simple panel regression analysis corrected for heteroscedasticity and autocorrelation. The estimated econometric model is good enough as indicated by the adjusted *R*-squared value, to explain the variations in GNPLs. The results suggest variables such as outstanding loan amount and average loan size per SHG are found to have a significant impact on the total amount of GNPLs in SHG-BLP. Both variables are positively associated with the GNPLs, which implies that an increase in the outstanding loan amount and average loan size per SHG would cause an increase in the total amount of GNPLs. Further, the outstanding loan amount seems to have a larger impact than the average loan size per SHG on the level of NPL.

Table 1. Progress of SHG-Bank Linkage Programme during 2007–08 to 2017–18.

Details of SHG-BLP	2007–08	2015–16	2016–17	2017–18
1. No. of SHGs with savings linkage (in lakh)	50.10	79.03	85.77	87.44
2. Amount of savings of SHGs (₹in crore)	3,785	13,691	16,114	19,592
3. No. of SHGs availed loans during the year (in lakh)	12.28	18.32	18.98	22.61
4. Amount of loans disbursed during the year (₹in crore)	8849	37,287	38,781	47,186
5. No. of SHGs with loan outstanding (in lakh)	36.26	46.73	48.48	50.20
6. Amount of loan outstanding (₹in crore)	17,001	57,119	61,581	75,598
7. Amount of NPLs (₹in crore)	423	3,686	4,002	4,628
Key ratios: SHG-BLP				
8. Savings amount to loan outstanding (row 2/row 6)	0.22	0.24	0.26	0.26
9. Loan outstanding to loan disbursed amount (row 6/row 4)	1.92	1.53	1.59	1.60
10. NPLs (row 7/row 6 × 100) (in %)	2.49	6.45	6.50	6.12

Source: NABARD, Status of microfinance in India, various issues and MFIN Website.

Table 2. Result of the Panel Regression Analysis.

Variable	Coefficient	Std. Error
C	–48.868***	4.210
LTOL	0.396***	0.063
LAVLS	0.161*	0.094
LSVD	–0.052	0.062
LGSDP	–4.651***	0.387
PVRTY	0.034**	0.015
LITR	–0.019	0.012
Model Fitness Statistics		
Adjusted *R*-squared	0.96	
F-statistic	198.751***	

Source: Authors' estimation using survey data.

Note: The symbol *, ** and *** express the level of significance at 10%, 5% and 1%, respectively.

Among the control variables, coefficients of the poverty rate and GSDP are found significant. This points towards the fact that economic the background of a state has a strong influence on the total amount of GNPLs in SHG-BLP. The higher negative coefficient of GSDP indicates that higher GSDP reduces the amount of GNPLs in the SHG-BLP. On the other hand, the poverty rate is positively related to GNPLs, which implies that an increase in the proportion of the population below the poverty line increases the amount of GNPLs in the SHG-BLP in a state. Therefore, it can be concluded that economic conditions in the states in terms of income growth and incidence of poverty have a profound influence on the amount of GNPLs of the SHG-BLP units operating there.

Incidence and Reasons of Loan Default by Sample SHG Members

In this section, we present the findings from the analysis of primary data collected through a sample survey carried out in three select states with an aim to understand the incidence and reasons for loan default by women SHG members. The demographic and socio-economic features of sample women SHG members influencing the loan defaults are summarised in Table 3. Regarding the age-wise distribution, about 65.8% of the sample respondents fall under the working-age group of 26–45 years. It is appalling to note that almost 75% of women SHG members interviewed are illiterate implying that they have not received any education. This higher proportion of illiterate members is a serious challenge to the smooth functioning and sustainability of SHGs and SHG-BLP. Because they may not be familiar with the banking activities and cannot make use of loans productively by investing in income-generating activities due to lack of awareness. Further, they can be easily exploited by the persons connected with the operation of SHG-BLP.

Table 3. Basic Features of Sample SHG Members.

Variable	Category	Frequency	Percentage
Age	≤25	23	3.5
	26–35	196	29.6
	36–45	240	36.2
	46–55	144	21.7
	≥56	60	9.1
Occupation	Unemployed	91	13.7
	Self-employed	9	1.4
	Non-agricultural labour	30	4.5
	Agricultural labour	343	51.7
	Others	190	28.7
Education level	Illiterate	497	75
	Up to 5th class	62	9.4
	Up to 10th class	72	10.9
	Intermediate	17	2.6
	Degree	15	2.3
Monthly income	Up to 5,000	273	41.2
	5,001–10,000	110	16.6
	10,001–15,000	107	16.1
	>15,000	173	26.1
Years of membership in SHG	1–3 years	111	16.7
	>3 <5 years	90	13.6
	>5 <7 years	37	5.6
	>7 <10 years	63	9.5
	>10 years	362	54.6
Monthly savings	No savings	128	19.3
	Up to ₹500	327	49.3
	₹501–1,000	140	21.1
	₹1,001–1,500	56	8.5
	Above ₹1,500	12	1.8
Number of loans taken	No loan	10	1.5
	1	174	26.2
	2	181	27.3
	3	197	29.7
	4	70	10.6
	>4	31	4.7
	Total	663	100

Source: Field Survey.

The occupational distribution shows that more than half of the sample SHG members are agricultural labourers. Resultantly the monthly incomes of the members are very low. About 41.2% of the respondents are earning less than ₹5,000 per month reflecting the subsistence living conditions of the SHG women. With respect to the experience of SHG members, 54.6% of the respondents are members of SHGs for more than 10 years. It is noteworthy to mention that SHG-BLP has created saving habits among women members. Nearly 31% of the sample SHG members save more than ₹500 per month after joining the SHG-BLP and almost half of them save an amount less than or equal to ₹500. It was observed during the survey that SHG members show a higher tendency to take loans from SHG-BLP to overcome various kinds of livelihood crises due to low rates of interest. Among the sample respondents, about 45% have taken 3 or more loans from the SHG-BLP and 27% of respondents have taken 2 loans. This is clear evidence of the higher level of indebtedness of the poor women, which is essentially a result of employment and livelihood distress experienced by them.

The incidence of loan default was found to be higher among sample respondents except in the case of MP. Table 4 shows the state-wise distribution of defaulters and non-defaulters in SGH-BLP. It can be observed that 44% of all sample SHG members have defaulted on the loan taken from SHG-BLP. In AP and Odisha, more than half of the SHG respondents have defaulted on the loans, and the percentage is as high as 65% in AP. However, in MP only 12% have defaulted on bank loans. Thus, the repayment rate is high in MP, though it represents the central Indian region, which has high NPLs in the SHG-BLP.

Further, we also enquired about the purpose of the loan taken and the reasons for loan defaults by SHG members based on their perceptions. The previous literature suggests that one of the primary factors responsible for the increasing level of NPLs is the non-productive end-use of the loans. Therefore, the study examined the pattern of utilisation of loans, whether they are utilised for income-generating activities *or* otherwise. The utilisation pattern has a crucial role in the repayment of loans because borrowing for non-income generating activities may increase the probability of default. Some of the SHG women may utilise the bank loans for consumption purposes, resultantly they may not be able to repay and consequently, these loans will be treated as NPLs.

Table 4. State-Wise Distribution of Defaulters and Non-defaulters in SHG-BLP.

Category	AP	Odisha	MP	All States
Non-defaulters	67	121	186	374
	(35)	(46)	(88)	(56)
Defaulters	122	142	25	289
	(65)	(54)	(12)	(44)
Total	189	263	211	663
	(100)	(100)	(100)	(100)

Source: Field Survey.

Note: Figures in parentheses represent percentage to column total.

It can be noted from Table 5 that most of the respondents utilised the loans for medical emergencies (36.9%), household consumption (36.8%), agricultural activities (35.9%), cattle rearing (34.5%) and children's education (30.7%) in that order. Roughly one-fourth of the SHG members informed that they repaid their past loans, and 21.5% was spent on marriage and other social functions. Sometimes, the poor take multiple loans, including from local money lenders, which are high-cost borrowings from the informal credit market; as such, repayment of high-cost debt results in great relief for the rural masses through the SHG-BLP, which is a low cost-financing model. While close to one-fifth of the respondents-built houses, only 17.3% of the SHG members started micro-enterprises. It is observed from FGDs that some of the SHG women have not started any micro-enterprises due to a lack of proper guidance and not having any technical/managerial skills and market linkages.

It is evident that only a few members have used loans for income-generating activities, therefore utilisation of loans for non-productive activities has been perhaps the main reason for the higher incidence of loan default among sample respondents. We enquired about the adequacy level of the loans extended to the members to undertake any economic activities. The results show that 62.9% of the respondents felt that the loan amount from the SHG-BLP is sufficient to undertake economic activities.[3] However, one-fourth (23.4%) of the sample respondents reported that the loan amount is not sufficient to engage themselves in any income-generating activity, and the rest 13.7% did not give any response. In fact, 44.3% of respondents from Odisha gave a negative reply in this regard. It is surprising to observe that 35.5% of the SHG members in AP did not respond as they might be unaware of the adequacy level of investment, or they might not have thought of

Table 5. Purpose of Loans Taken by SHG Members.

Sl.No.	Purpose/End Use of Loan	Percentage (All Three Sample States)	Rank
1	Medical emergency/healthcare	36.9	1
2	Household/personal consumption	36.8	2
3	Agriculture	35.9	3
4	Rearing of cattle	34.5	4
5	Children's education	30.7	5
6	Repayment of past loans	25.5	6
7	Marriage and other social functions	21.5	7
8	House construction	20.5	8
9	Petty business shop/micro-enterprises	17.3	9

Source: Field Survey.

Note: Summation of the figures in percentage is not equal to 100 as a single respondent might have used the loan(s) for various purposes or availed multiple doses of credit for different end uses.

starting any (micro) enterprise at all. Nevertheless, the above findings may act as the right feedback for the lenders.

Besides, we asked a question about whether the respondents repaid the loans taken from the banks under the National Rural Livelihood Mission (NRLM) program to understand the repayment behaviour of the SHG women towards government schemes. We found that 45.7% of the SHG members have not repaid these loans; out of these, MP and AP accounted for the major portion of the loan defaulters. During FGDs, it is reported that most of the defaulting members received the above loans before 2012 as part of the SGSY scheme, wherein the government subsidy component was available. This could be the reason for the non-repayment of the loans since the SHG borrowers might have thought that the entire SGSY loan amount was subsidised.

We also analysed the overdue period of NPLs in the program and the responses are presented in Table 6. It is found that 82.5% of the loans are overdue for more than 3 months in the SHG-BLP. It is observed that 36.4% of the total respondents admitted that they have loans overdue for beyond 36 months; basically, these are loss assets in the books of banks, which could be written off as there is very little chance of recovery (collateral-free loans). However, it is good to see that 6.9% of the respondents from Odisha reported that they did not have any overdue. Similarly, about 40.6% of SHG-women in MP (40.6%) reported that they had overdue for less than 3 months (which are performing assets in the books of banks).

The main factors responsible for NPLs as perceived by SHG members are also examined. The responses of the SHG members are reported in Table 7. It is seen that majority of the respondents cited poor economic conditions (56.3%), non-cooperation among members of the SHG (48.4%), social expenses towards marriage/ceremony/medical emergency, etc. (42.1%), and expectation of loan waiver from the government (35.9%) in the order, as the main factors behind the unhealthy growth of NPLs. Most of the SHG members are poor people at the bottom of the pyramid, employed in farm activities and struggle for existence under unfavourable market conditions. The agrarian and employment distress experienced by these poor women perhaps caused the default of the repayment. Poor economic conditions of the SHG women may lead to migration to urban

Table 6. Dues of Bank Loans of SHG Members in Months (Figures in Percentage).

Period of Dues/State	Andhra Pradesh	Madhya Pradesh	Odisha	All Three States
Reported no dues	0.0	0.0	6.9	2.7
Less than 3 months	4.2	40.6	1.5	14.8
Above 3 months but less than 36 months	39.7	50.0	47.7	46.1
Above 36 months	56.1	9.4	43.9	36.4
Total	100	100	100	100

Source: Field Survey.

areas in search of livelihoods. As such, there were overdue from these SHG women turned migrant labourers.

It is observed that other group members repaid the overdue on behalf of the seasonal migrant labourers on a few occasions but could not do so every time. It was realised during the FGD that the cooperation among the members was good during the initial phase (formation stage) of the SHG-BLP; however, the spirit of cooperation deteriorated slowly after the loan was disbursed. In a few cases, it is noticed that a single member in the group availed more than half of the loan amount (with the consent of other members) and when she did not repay, all other members were treated as defaulters. It is noticed from the data that non-cooperation existed more in the case of the SHG-women defaulters in AP and Odisha, which was reflected in the higher incidence of NPLs in these states.

Further, it was found that 84% of the SHG members from MP agreed that social expenses for marriages, ceremonies and medical emergencies contributed to the non-repayment of loans. It is interesting to observe nearly 70% of the SHG members from AP cited expectations of a loan waiver from the government as a

Table 7. Main Reasons behind NPLs (Figures in Percentage).

		AP	MP	Odisha	All Three States
Sl. No.	Reason for Overdue	Yes	Yes	Yes	Yes
1	Poor economic conditions of the SHG members	59.8	68.9	43.5	56.3
2	Non-cooperation/non-repayment by other members of the SHG	83.1	20.7	45.8	48.4
3	Expenses towards marriage/ceremony/medical emergency, etc.	17.5	84.0	26.0	42.1
4	Expectations of loan waiver from the government	69.3	25.5	20.2	35.9
5	Natural disasters like drought, cyclones, floods, earthquakes, etc.	3.7	41.5	39.0	29.7
6	Family disputes/misunderstanding among members of the family with regard to financial matters	46.6	18.4	17.5	26.1
7	Lack of proper follow-up from banks	28.0	27.8	21.7	25.5
8	Higher interest rates	24.9	36.8	1.2	19.3
9	Death/migration of member(s) of SHG to other areas	28.6	13.7	10.7	16.7
10	Multiple sources of borrowings	24.9	12.7	3.8	12.7

Source: Field Survey.

Note: (i) Only positive responses of the respondents in respect of each state is mentioned; the balance represents negative responses; (ii) Sum of the figures in percentage is not equal to 100 as a single respondent might have used the loan(s) for various purposes or availed multiple doses of credit for different end uses.

major reason behind the bad loans. The SHG women mentioned that natural disasters (29.7%) and family disputes (26.1%) as other prominent reasons behind the NPLs. It may be noted that all three study states are prone to natural calamities, which affect the agricultural income directly and other activities indirectly in the rural areas resulting in loan defaults to banks. Contrary to the popular belief that only one-fourth of the SHG members (25.5%) agreed that lack of proper follow-up from the banks is one of the reasons for their loan defaults. The majority of the SHG members gave a negative answer regarding regular repayment of loans (75.1%), regular internal lending (72.2%), regular rotation of leadership positions (71.5%) and regular savings (54.6%). In fact, irregular internal lending results in fewer economic activities and the generation of lower income and ultimately leads to NPLs. Similarly, non-rotation of leadership positions of SHGs will lead to concentration of power and dominance of certain class/group members in the SHG and consequent non-cooperation among themselves. Regular savings act as cushion pads in the lives of SHG women. The SHGs can become 'Self-Help' groups only if they follow the above activities in letter and spirit.

Determinants of Loan Defaults by SHG Members

Logit regression analysis is carried out to understand the major determinants of loan defaults by SHG members and the results are reported in Table 8. The table also contains hypothesised signs between independent and dependent variables of the regression equation specified earlier. The coefficient values are reported as *odds ratio* and hence one may note that when the odds ratio is greater than one, it describes a positive relationship between the respective independent variable and dependent variable and vice versa. The lower panel of the table reports the goodness of fit statistics of the model. A highly significant LR chi^2 suggests that at least one of the predictor's coefficients is not equal to zero reflecting the overall significance of the model. The estimated value of McFadden's pseudo *R*-squared is 0.409, which suggests that the full model is better than the model with only an intercept. The significant coefficient of the predicted (hat) value and the insignificant value of the predicted value squared (hatsq) indicate that the model is correctly specified. The insignificant value of Hosmer–Lemeshow chi^2 indicates that the model fits the data well.

The coefficient values of all the age categories are highly significant and are greater than one. This indicates that when the age of the SHG-BLP member increases, the probability of her being a defaulter also increases. This is mainly due to the increasing responsibility in the family. Surprisingly, the members with degree education (members with higher education in SHG-BLP) are found to be more likely to default on the loan repayment, plausibly due to expectations of loan waiver. Further, the members with self-employment as an occupation are found to be less likely to default on repayment of the loan possibly due to income-generating cash flows. Similarly, the higher income group, that is, members whose income is more than ₹15,000/- per month is less likely to default on repayment of the loan. Therefore, the nature of employment and level of income

Table 8. Results of Logit Regression.

Variable/Code	Odds Ratio	Std. Error	*Z* Value	Hypothesised Sign
Age (≤25: Reference)				
26–35	42.492***	55.526	2.870	+
36–45	53.277***	68.692	3.080	
46–55	62.963***	82.265	3.170	
≥56	90.087***	119.702	3.390	
Education level (Illiterate: Reference)				
Up to 5th class	1.076	0.407	0.190	–
Up to 10th class	1.693	0.649	1.370	
Intermediate	1.376	1.030	0.430	
Degree	6.030**	5.405	2.000	
Occupation (Unemployed: Reference)				
Self-employed	0.320**	0.179	–2.040	+/–
Non-agricultural labour	1.592	0.505	1.470	
Agricultural labour	1.020	0.410	0.050	
Others	0.788	0.889	–0.210	
Monthly income (Up to ₹5,000: Reference)				
₹5,001–10,000	0.907	0.291	–0.300	–
₹10,001–15,000	0.626	0.223	–1.310	
>₹15,000	0.4731***	0.135	–2.620	
Years of membership in SHG (1–3 years: Reference)				
>3 <5 years	1.900	1.459	0.840	+/–
>5 <7 years	10.852***	7.659	3.380	
>7 <10 years	39.349***	25.252	5.720	
>10 years	90.900***	56.304	7.280	
Number of loans taken (No loan: Reference)				
1	14.449***	12.960	2.980	–
2	4.031	3.502	1.600	
3	3.699	3.227	1.500	
4	1.747	1.596	0.610	
>4	0.705	0.675	–0.360	
Monthly savings (No savings: Reference)				
Up to ₹500	0.239***	0.073	–4.670	–
₹501–1,000	0.274***	0.111	–3.190	
₹1,001–1,500	1.017	0.624	0.030	
Above ₹1,500	1.668	1.566	0.550	
_cons	0.000***	0.000	–5.100	
Model fitness statistics				
LR $chi^2(7)$			371.930***	
Pseudo R^2			0.409	
Hat			1.002***	
Hatsq			0.003	
Hosmer–Lemeshow $chi^2(8)$			2.84	
Mean VIF			1.12	

Source: Authors' estimation using survey data.

Note: Symbols *, ** and *** express the level of significance at 10%, 5% and 1%, respectively.

exerts a significant impact on loan default by SHG members. The more the number of years of membership with the SHG (say above five years), the higher the probability that she defaults on the loan repayment. This happens because the SHG women receive a higher amount of loans from banks after five years, by which time she might have been out of poverty and she may not have any incentive to repay the loan.

The member whose monthly saving amount is up to ₹1,000/- is less likely to default when compared to the member with nil savings. Saving reduces the probability of defaulting loans. The significant coefficient of one loan implies that the members are more likely to default in the first instance of borrowing itself. This is plausibly due to the use of loan proceeds for consumption purposes or social functions rather than an income-generating activity by the defaulting member(s). Further, the SHG members may be influenced by the promises of loan waivers by the political parties, which resulted in bad loans on the books of banks and financial institutions.[4]

Summary and Policy Implications

The SHGs touch upon four to five lives in every member family and enable them to access better food, clothing, shelter, healthcare, education and aspirational lifestyle apart from realising the dream of entrepreneurship/decent livelihoods. Though the SHG-BLP achieved many a milestone during the last two and a half decades, it accumulated huge GNPLs in the last few years; the GNPLs of the SHG-BLP surged from ₹423 crore in 2007–08 to ₹4,628 crore in 2017–18. Hence, there is every reason to arrest this trend and make the SHG-BLP, a sustainable model by evaluating its loan portfolio in terms of NPLs. Therefore, in this article, we carried out both macro- and micro-level analyses on the determinants of NPLs. The study noted that GNPLs, both in absolute terms and as a percentage of the total loan outstanding, have been increasing over the last decade. The results from panel regression analysis with secondary data show that average loan size per SHG, total outstanding loan amount and poverty rate positively influence GNPLs in the SHG-BLP, while gross state domestic product has an inverse relation. Thus, it is inferred that economic conditions in the state play a vital role in determining the level of GNPLs in the SHG-BLP.

Analysis of primary data revealed that there is a higher extent of the incidence of loan defaults among the SHG members. There is a higher tendency among SHG members to utilise loans for non-productive activities, and this increases the chances of default. The major reasons perceived by the SHG members for the loan defaults are poor economic conditions, non-cooperation among the members of SHG, social expenses and expectations of a loan waiver from the government. It is observed that some defaulters in the SHG-BLP are influencing other group members not to repay the bank loans (herd behaviour) as loan waiver schemes may be announced during the election season. The lesser the government's intervention, the better the recovery scenario. Hence, there should not be any loan

waiver promises from the political parties as the same may slow down the institutional credit to the SHGs in the long run. This ultimately results in the creation of structural barriers to the sustainability of the SHG-BLP. Instead of loan waivers, the government may continue to extend interest subvention to the SHGs. Further, community resource persons may act as counsellors to resolve family disputes. For instance, Oravakal Mandal Podupu Lakshmi Ikya Sangham (OMPLIS) has such family counsellors for its SHGs in AP.[5]

Our results also show that when the SHG women are self-employed, earning more than ₹15,000 and saving up to ₹1,000 per month, they are less likely to default on loans to banks. Further, the SHG members who are self-employed are found to be less likely to default on repayment of the loans possibly due to income-generating cash flows. Hence, the SHG members should be encouraged to invest in micro-enterprises by providing constant training on technical know-how, literacy (basic, financial and digital forms) and market linkages as provided by Mahila Arthik Vikas Mahamandal Nigam (MAVIM).[5] This would ultimately translate into the generation of more income through the creation of assets and consequent lower NPLs in the SHG-BLP (Swain & Varghese, 2009).

Further, these SHG borrowers should be trained in marketing skills to excel in income-generating activities as in the case of Rural Women's Initiative for Self-Sustained Enterprises (RISE).[7] SHG women may be encouraged to obtain Geographical Indication tags for their products and services to create brand image thereby receiving remunerative prices. Also, the SHG members should be given flexibility in repayment of bank loans (ex: weekly repayment schedule) based on their sources of income/cash flows as stipulated by the Shri Kshetra Dharmasthala Rural Development Project (SKDRDP).[8]

Banks need to review the adequacy level of loans extended and assess the financial needs of the SHG borrowers in line with the actual requirement. As the loans sourced from local money lenders are high-cost borrowings, SHG members should be encouraged to rely more on the SHG-BLP through prompt repayment behaviour. Banks may negotiate with the SHG borrowers in respect of chronic NPLs to work out an amicable solution or restructuring of loans, if possible. Group insurance or microinsurance (life insurance as well as health insurance) may be promoted in a big way so that issues like death, partial disability, migration and bankruptcy of the poor SHG members will be addressed. MFIs in Bangladesh support the borrowers during natural calamities through write-off or rephasement of loans, hence distress among the farmers or borrowers appears to be low in that country. With a view to minimising multiple sources of borrowings and NPLs, an exclusive credit bureau for the SHGs needs to be established; this will ensure real-time, reliable, transparent and authentic information to track the borrowers' credit history. E-Shakti is the right digital initiative from NABARD in this direction, which can be extended to all districts in India.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship and/or publication of this article: The authors gratefully acknowledge the generous financial assistance of National Bank for Agriculture and Rural Development (NABARD) in conducting the research study (Grant No: SHG-BLP NABARD C-1714).

Notes

1. We have taken natural log of variables such as NPL, total outstanding loan amount, saving deposits, average loan amount and GSDP.
2. Further, we assumed a linear growth rate while interpolating the values of poverty and literacy rate.
3. We have excluded some tables to achieve brevity; however, they can be provided on request.
4. From our field survey, we understood that SHG members are likely to default if they take either one loan only or multiple doses of credit (say more than 10 times), by which time they will cross the poverty line. However, the SHG members are very consistent in repayment of their loans during the middle part of the entire spectrum. As such, it is deducted that the chances of default by SHG members are higher during the initial and last phases of their membership in the SHG-BLP.
5. Oravakal Mandal Podupu Lakshmi Ikya Sangham (OMPLIS) is an SHG federation based in Kurnool, Andhra Pradesh with a membership of over 10,000 rural women.
6. Mahila Arthik Vikas Mahamandal Nigam (MAVIM) was implemented as Tejaswani project in Maharashtra for the development of women with funding from the International Fund for Agriculture Development.
7. Rural Women's Initiative for Self-Sustained Enterprises (RISE) is a project funded by Vodafone Foundation to encourage income-generating activities and to develop marketing skills through technology among the rural poor women in India.
8. Shri Kshetra Dharmasthala Rural Development Project (SKDRDP) is an NGO and charitable trust based in Karnataka with an SHG loan portfolio of around ₹10,000 crore.

References

Aidoo, M., & Mensah, F. S. (2018). The causes of default loans risk in microfinance institutions in Ghana: Case study of some selected microfinance institutions in Kumasi and Accra. *Global Journal of Management and Business Research*, *18*(2), 22–276.

Al-Kubati, N. A. A., & Selvaratnam, D. P. (2021). Empowering women through the self-help group bank linkage programme as a tool for sustainable development: Lessons from India. *Community Development Journal*, 1–26.

Aluni, S. N., & Ray, S. (2015). Road to sustainable SHG-bank linkage program: Formulating strategies for managing credit risk with respect to rural Bengal. *IIM Kozhikode Society and Management Review*, *4*(2), 146–151.

Anand, J. S. (2002). Self-help group in empowering women: Case study of selected SHGs and NHGs (Discussion Paper No. 38). Kerala Research Programme on Local Development, Centre for Development Studies, Thiruvananthapuram. http://www.cds.ac.in/krpcds/w38.pdf

Banerjee, V. A., & Duflo, E. (2011). *Poor economics: Rethinking poverty & the ways to end it*. Vintage Books.

Chikalipah, S. (2018). Credit risk in microfinance industry: Evidence from sub-Saharan Africa. *Review of Development Finance*, *8*(1), 38–48.

Deshpande, V., Sharma, D., & Kailash, C. (2016). Self-help group bank linkage programme in India as a means of financial inclusion—Status and emerging challenges. *African – Asian Journal of Rural Development*, *49*(2), 84–104.

Guha, B., & Chowdhury, P. R. (2013). Micro-finance competition: Motivated micro-lenders, double-dipping and default. *Journal of Development Economics*, *105*(5), 86–102.

Gupta, M., Zwi, A. B., & Jagnoor, J. (2020). Opportunities for the development of drowning interventions in West Bengal, India: A review of policy and government programs. *BMC Public Health*, *20*(1), 704. DOI: 10.1186/s12889-020-08868-2.

Harper, M. (2002, November 25–26). Promotion of self-help groups under SHG-Bank linkage programme in India [Paper presentation]. Seminar on SHG-Bank linkage programme at New Delhi.

Hundekar, V. R., & Munshi, M. M. (2020). The economic impact of SHG-BLP on the empowerment of rural women in India. *IUP Journal of Bank Management*, *19*(3), 52–72.

Karmakar, K. G. (2009). Emerging trends in microfinance. *Economic and Political Weekly*, *44*(13), 21–24.

Kumar, N. K. (2016). Microfinance-plus services-from access to impact: Empirical evidence from rural India. In M. Jayadev, & K. S. Daitha (Eds.), *Changing contours of microfinance in India*. Routledge.

Mahapatra, M. S., & Dutta, S. (2016). Determinants of sustainability of microfinance sector in India. *Journal of Rural Development*, *35*(3), 507–522.

Mani, N. (2015). *Financial inclusion in India: Policies and programmes*. Century Publications.

Mohapatra, N. P. (2016). This is financial inclusion. *Economic and Political Weekly*, *41*(41), 4310–4313.

NABARD. (2018a). *NABARD All India Rural Financial Inclusion Survey* 2016–17. https://www.nabard.org/auth/writereaddata/tender/1608180417NABARD-Repo-16_Web_P.pdf

NABARD. (2018b). *Status of micro-finance in India* 2017–18. https://www.nabard.org/content.aspx?id=651

Nawai, N., & Shariff, M. N. M. (2012). Factors affecting repayment performance in microfinance programs in Malaysia. *Procedia-Social and Behavioral Sciences*, *62*(1), 806–811.

NIRDPR. (2019). *An evaluation of the SHG-BLP with special reference to its loan portfolio and asset quality*. http://nirdpr.org.in/nird_docs/rss/rs070120.pdf

Oommen, M. A. (2018). *Micro finance and poverty alleviation: The case of Kerala's Kudumbashree* (Working Paper No. 17). Centre for Socio-economic & Environmental Studies.

Parida, P. C., & Sinha, A. (2010). Performance and sustainability of self-help groups in India: A gender perspective. *Asian Development Review*, *27*(1), 80–103.

Peng, C. Y. J., Lee, K. L., & Ingersoll, G. M. (2002). An introduction to logistic regression analysis and reporting. *The Journal of Educational Research*, *96*(1), 3–14.

Puhazhendi, V., & Badatya, K. C. (2002, November 25–26). *SHG-bank linkage programme for rural poor—An impact assessment* [Paper presentation]. Seminar on at e-Social Sciences, New Delhi.

Raj, B. (2012). Revisiting the SHG-BLP. *The Indian Banker*, *7*(7), 23–31.

Ramanathan, A. (2007). Financial inclusion in India through SHG-Bank linkage programme and other finance initiatives by NABARD. In: *Issues Paper presented at Financial Globalization Conference* 22–23 Nov, 2007, India.

Rajeev, M., Vani, B. P., & Veerashekharappa. (2020). Group lending through an SHG banklinkage programme in India: Transaction costs and social benefits. *Development in Practice*, *30*(2), 168–181. DOI: 10.1080/09614524.2018.1508418.

Reji, E. M. (2010). What makes self-help groups successful? *Journal of Rural Development*, *29*(1), 89–96.

Singh, S. (2008). *Microfinance in India*. SAGE Publications.

Sinha, A., Parida, P. C., & Baurah, P. (2012). The impact of NABARD's self help group-bank linkage programme on poverty and empowerment in India. *Contemporary South Asia*, *20*(4), 487–510.

Srikanth, M., & Reddy, W. R. (2017). An evaluation of financial inclusion in India: Some policy insights. *Microfinance Review*, *9*(2), 1–14.

Srinivasan, N. (2008). Sustainability of SHGs in India. In K. G. Karamakar (Ed.), *Micro finance in India* (pp. 177–178). SAGE Publications.

Subrahmanyam, N. (2009). Micro finance and SHG-bank linkage: Regional analysis and perspectives. *Prajnan*, *38*(3),183–202.

Sukanya, N. (2017). The SHG-bank linkage programme and financial inclusion in India: A review of the recent trends. *GITAM Journal of Management*, *15*(2), 33–42.

Sundaram, D. A. (2012). Impact of self-help group in socio-economic development of India. *IOSR Journal of Humanities and Social Science*, *5*(1), 20–27. DOI: 10.9790/0837-0512027

Swain, R. B., & Varghese, A. (2009). Does self-help group participation lead to asset creation? *World Development*, *37*(10), 1674–1682.

Sign up for FREE updates about the latest research!

journals.sagepub.com/action/registration

Register online at SAGE Journals and start receiving…

New Content Alerts

- Receive table of contents alerts when a new issue is published.
- Receive alerts when forthcoming articles are published online before they are scheduled to appear in print (OnlineFirst articles).

Announcements

- Receive need to know information about a journal such as calls for papers, special issue notices, and events.

Search Alerts

- Create custom search alerts based on recent search keywords or terms.

journals.sagepub.com

SAGE journals

SAGE journals

Home to over 1,000 SAGE journals in business, humanities, social sciences, and science, technology, and medicine.

SAGE's prestigious and highly cited journals are available electronically on ***SAGE Journals*** now hosted on its new online platform. Search and browse more than 1,000 journals by discipline — including journals in business, humanities, social sciences, and science, technology, and medicine.

SAGE Journals includes:

- Search and browse journals across 50+ disciplines
- Show Abstract – expand Abstract information from tables of contents and search results allowing you to preview the abstract without leaving the page
- Popular article lists – most-read and most-cited articles lists available from each journal's homepage
- Follow-me navigation – content features follow alongside as you scroll down the article page (full-text journals)
- My Tools features including New Content Alerts, Search Alerts, and My Favorite Journal lists
- OnlineFirst articles - forthcoming articles published ahead of print
- Streaming video (select titles)
- Pop-up references – full citations pop up when you hover over reference numbers within the text of an article (full-text journals)
- Keyword pivot searches – hyper-linked article keywords allow you to perform quick searches of that term across all journals
- Article level metrics--including both Altmetric data (where available) and download statistics
- Author information services including viewing all articles by this author on SAGE Journals, links to Google Scholar, and new
- Article share features include 'email a friend' and social bookmarking options
- RSS feeds
- Podcasts (select titles)

Get started today!

journals.sagepub.com

SAGE journals