Content list available at http://epubs.icar.org.in, www.kiran.nic.in; ISSN: 0970-6429

Indian Journal of Hill Farming

Special Issue 2021, Volume-34, Page 121-128

Adoption rate and impact of pig production technologies in the tribal production system of North eastern hill region of India

G. Kadirvel • Sourabh Deori* • Keshab Jamatia

ICAR Research Complex for NEH region, Umiam, Meghalaya-793103, India

ARTICLE INFO

Article history:
Received: 17th January 2020
Revision Received: 18th January 2020
Accepted: 27th January 2020

Key words: Adoption rate, Pig Production Technologies, Eastern Himalayan Ecosystem, Livelihood, Smallholder Pig Production System

ABSTRACT

The study was conducted with the objective to assess the knowledge level of tribal farmers, perception and adoption rate of technologies in tribal pig production system and impact of technologies in terms of productivity, livelihood improvement, and nutritional enhancement of tribal farmer in the targeted village. A total of 1800 tribal farmers were selected from 90 villages under nine blocks from three districts viz. East Khasi Hills, Ri-Bhoi and West Jaintia Hills of Meghalaya for studying. Survey was done using pre-tested interview schedule. The technologies selected for assessment are Synthetic pig variety: Lumsniang-a synthetic pig variety; Three breed cross pig variety: Niang Megha x Hampshire x Duroc; Artificial Insemination Technology; Low cost housing; Deworming and vaccination; Vermicomposting and manure production and Waste water recycling. The tribal farmers obtained two-fold increase in income from rearing of crossbred pigs as compared to rearing of local pig. The study concluded that popularization of crossbred pigs with improved management practice, AI and other technologies leads to improvement in productivity, income and livelihood of tribal farmers in the ecosystem.

1. Introduction

Piggery is an integral component of animal husbandry in the entire north eastern hill region of India. It is the key role to improve the livelihood of the farmers. Almost every tribal household in the rural areas rear 2-3 numbers of pigs for different rituals and economic return through sale of excess piglets. Pig farming has offered substantial scope for poverty reduction among tribal farmers. Pork is most sought after meat in the entire region and the demand is always high all the time. However, the supply of pork is not adequate to meet the demand and there is flow of live pigs from outside the region to fulfil the required gap. The main reason for low productivity of pigs of the region is traditional system of rearing with no scientific interventions and non-availability of good quality germplasm. Low productivity from local pig is due to smaller litter size, high mortality and non- scientific management. Lack of awareness among the native population regarding scientific pig farming is one of the major constraint that slows down the improvement of piggery sector in the region. Introduction of good quality germplasm, scientific housing, feeding and management, routine vaccination and health care management are some of the key factors for the improvement of pig production. The present study is carried out with an objective to study the knowledge level of pig farmers, perception and adoption rate of technologies in tribal production system and impact of technology in terms of productivity, livelihood improvement, income and nutritional enhancement of tribal farmer in the targeted village.

2. Materials and Methods

Location of the study: The present study carried out in the state of Meghalaya, which is located in the eastern Himalayan region of India and consists of three major hills named after three predominant tribes i.e. Khasi Hills, Garo Hills and Jaintia Hills. The study area lies between longitude 91.366°E and latitude 25.4670°N and has height of 1,010 m above mean sea level and experience a high amount of rainfall annually (2,239 to 2,953 mm/year). It is characterised by temperate and sub-tropical climate with average maximum and minimum temperature ranging from 21.1 to 29.2°C and 7.0 to 20.9°C respectively. Farmers in the prevailing study area practice traditional pig rearing in the form of backyard low input production system (Kadirvel *et al.*, 2013).

*Corresponding author: sourabhd1@rediffmail.com

Sampling methods: Base line information on socio-economic condition of the pig rearing tribal farmers were collected in three districts viz. East-Khasi Hill, Ri-Bhoi and West-Jaintia Hill. From each of the districts, three blocks were selected randomly, making the total number of block equal to nine. Again, 10 villages from each block were selected randomly and 10 farmers from each village were chosen, making the final sample size equal to 1800 farmers. The Survey was conducted using a pre-tested interview schedule, designed to collect the socio-economic profile of the pig rearing tribal farmers and the information on agricultural land holding and pig production system.

The information of the pig production system included type of pigs reared, purpose of rearing, herd size, housing, feeding, breeding, health care and disease incidences. The study also identified the constraints faced by the tribal farmers selected as respondents. The knowledge level of the selected tribal farmers on pig management was studied using score tool following the Likert's scale which ranges from one to five (one is assigned as poor, two as moderate, three as good, four as very good and five as high knowledge level).

A total of 275 pig farmers were selected and trained on improved pig production systems. After the successful training, the farmers were provided with technological backup and critical inputs including crossbred pig variety, concentrated mesh feed and mineral mixture, besides the provision of health care management. The performance of crossbred piglets variety were monitored at a monthly interval for recording their health, growth rate and reproductive parameters. These farmers were also advised to carry out regular deworming and vaccination and to follow improved management practices including preparation of low cost feed formulation with locally available feed resources.

The knowledge level of tribal farmers on pig husbandry was studied after four years of training and demonstration using the scoring tool following the Likert scale. The performance of crossbred pig variety was compared with the local pigs under the existing production systems. For this purpose, total 220 piglets were selected randomly for productive performance i.e. 120 crossbred piglets and 100 local piglets from the selected villages. For reproductive performance, 60 crossbred sows and 60 local sows, which were randomly selected from the villages in study area. The study assessed the economic benefit of crossbred pig variety raised for fattening as well as breeding against the local pigs. Change in livelihood of 200 farmers was also assessed.

Selection of technologies: The technologies selected for assessment are Synthetic pig variety: Lumsniang-a synthetic pig variety; Three breed cross pig variety: Niang Megha x Hampshire x Duroc; Artificial Insemination Technology; Low cost housing; Deworming and vaccination; Vermicomposting and manure production and Waste water recycling.

Data collection: Data was collected for body weight of local and crossbred pigs at 2, 4, 6 and 8 months and different reproductive traits for different categories of pigs. For effect of AI technology, data pertaining to farrowing rate and litter size at birth are recorded. The body weight at different age, disease incidence and mortality were recorded and compared in the pigs raised in the low cost housing and concrete floor. Morbidity and mortality rate were recorded before and after implementation of deworming and vaccination in the pig herds. Data pertaining to pig dung based vermicompost and pig shed waste water recycling were collected. Change in livelihood of 200 farmers was also assessed before and after four years of demonstration using a modified format of the original livelihood format developed by Dutta and Guchhait (2018). The original format is modified based on the convenient and relevance to the study area. Livelihood index value was measured by five types of livelihood asset capital i.e. Human Capital, Natural Capital, Financial Capital, Physical Capital and Social Capital and relevant indicators had been designed and utilized. The indicators were considered based the reality of the study area to provide reliable and meaningful interpretation. Majority of the indictors had been determined using rating scale methods in terms of different weightages. The three critical values of 0.33, 0.66 and 1 interpreted as Poor, Average and Good, respectively and four critical values of 0.25, 0.50, 0.75 and 1 had been considered as Poor, Average, Good and Very Good respectively. While the two critical values of one and zero was taken as Yes and No (Muangkaew and Shivakoti, 2005). The number of observation of the respondents were converted into percentage and multiplied by the respective score which was followed by addition of all the score values to give the index values. The score was then recorded for analysing the livelihood level before and after technological intervention on improved pig production practices. The method to calculate the above livelihood index consideration is given below:

The first involves questions in the form of three answer choices: Good, Average, and Poor.

I=Good%×1+Average%×0.66+Poor%×0.33

The second involves questions in the form of four answer choices: Good, Average, and Poor.

I=Very Good%×1+Good%×0.75+Average%×0.66+Poor%×0.33

The third addresses questions in the form of perception in two choices: Yes and No.

I=Yes%×1+No%×0

After weight calculation, the value of each type of capital (C) was derived. The integrated measurement equation was developed as follows:

$$C=\sum (I_n/T_n)$$

Where **C** is the criteria score for each asset or capital ($0\leq C\leq 1$), **n** denotes nth indictor of criteria (n = 1, 2, 3, . . . n); **I** denote indicator; **T** denotes the total number of indicators.

Statistical Analysis: The data on productive and reproductive performance of crossbred pig and improved poultry, cost-benefit ratio and livelihood of the pig and poultry rearing tribal farmers were statistically analysed and compared using different parameters between crossbred and local pigs applying the SPSS software. The values are presented in percentage, mean, standard error and at 5% level of significance.

3. Result and Discussion:

Existing Pig Production System: The study revealed that the farmers were rearing pigs in typical traditional low input production system utilizing the locally available agro-based resources as the main source of feed for the pigs. The majority (68.7%) of the tribal farmers were rearing local pigs. The Majority of the pigs were being reared for the purpose of fattening (70.3%) and rest for breeding purposes. In the study, it was observed that 100% of the pigs were being reared in pigpen and the farmers generally followed the practice of stall-feeding. On the contrary, majority of farmers in a study in central and southern India follows free-range system of pig rearing (Majunder *et al.,* 2020).

The feeder and waterier found in the pigsties were predominantly made up of wood (65.67 %), concrete (35.15 %) and plastic/ rubber container (19.24%). In the study area, pigpen constructed with locally available materials and near the vicinity of the respondents' house. About 40% of the sties had floor and side- wall constructed with wood, while 20 % had floor and sidewall made of concrete with tin roof. Majority (80%) of the pigsties were covered with tin roof and 20% of them had roofs made of tach or plastic sheets. Appropriate shelter is necessary for pigs to protect rain and cold wind in the region. Since the region receives high rainfall of 2500- 3000 mm annually. Thus, most of the respondents used tin as roofing of pigpen material. Similarly, other studies found that locally available materials utilized for constructing pigsty in the region (Talukdar *et al.,* 2019).

With respect to feeding, about 63% of farmers fed the pig solely on locally available feeds. Only 28 % of the respondents were feeding pigs with purchased feed ingredients and remaining 9 % of the farmers were feeding readymade mixed feed along with locally available feed resources. Other studies (Kadirvel *et al.,* 2013; Talukdar *et al.,* 2019) and Shyam *et al.*, 2017) have also reported that locally available agro-based feed was being used in feeding pigs. Other researches also reported that both concentrate and local agro waste fed to pigs in Eastern Himalayan (Moanaro*et al.,* 2011; Kath *et al.*, 2019). About feeding frequency, majority of the tribal farmers (78.87 %) where feeding pigs twice a day and remaining 28.30% of them were feeding pigs thrice in a day. Similar to our study, other researchers also found that majority of their respondents fed pig twice in a day (Majunder *et al.,* 2020).

The study evaluated the knowledge enhancement of tribal farmers through training and demonstration on improved pig production and management. The study revealed an improvement of 68.75% (scale 4) and 31.25% (scale 3) in all the activities related to pig husbandry after training and demonstration. The mean value of knowledge of tribal farmers has increased from 1.625 to 3.687 after training and demonstration. Similarly, the knowledge and skill had improved by two fold through training and demonstration was recorded earlier (Kadirvel *et al.,* 2013). The study evaluated the performance and economic-benefit of crossbred pig variety with improved production system over existing local pig with improved production system.

The technology adoption rate of the tribal farmers in the pig production system is presented in table 1.

Table 1. Technology adoption, feedback and remarks by tribal farmers in Pig production system

Broad category	Traits	Adoption rate (%)	Feedback and Remarks
Synthetic Crossbred pig variety	Better physiological adaptation, higher productive and reproductive performance as compared to existing local pigs	87.5	Farmers are very happy with the technology due to multiple benefits, higher income as compared to existing local pigs
Three breed crossbred variety	Better physiological adaptation, suitable for lean meat production	65.0	Farmers are happy with the technology but demand of the technology is more in urban areas because of lean meat production.

Artificial Insemination Technology	Cost effective method for dissemination of improved germplasm, crossbred piglets are available at farmer's doorstep thereby increasing the profitability	78.0	Farmers are happy with Artificial Insemination technology due to saving of mating cost (Rs. 1500.00 to Rs. 2000.00) and transport cost of estrus female pigs during natural mating.
Low cost feed formulations with locally available ingredients (Banana pseudostem, Palm oil sludge, brewery waste etc)	Low cost feed has comparative growth rate of piglets with concentrate feed and lower production cost.	76.7	Farmers adopted the technology as feed ingredients are locally available and no dependency on external sources for concentrate feed. Optimum body growth rate. Only issue is time consumption in preparation of the feed.
Climate resilient ow cost housing	Better micro-environment, faster growth rate and less disease incidence. Higher water use efficiency and manure production.	71.2	Farmers are happy with the technology because pig shed is prepared with locally available resources like bamboo, wood etc. Model is sustainable. Only issue raised is regular changing of bedding materials.
Deworming and Vaccination	Less disease incidence and lesser mortality	90.0	Farmers readily adopted the technology. The only issue is availability of vaccines.
Vermicomposting and manure production	Efficient use of pig dung and hygienic pig production	61.3	Farmers are happy with the technology because of high quality of manure production from pig dung, but input cost are higher
Waste water recycling	Higher water use efficiency, recycling of pig shed waste water for shed cleaning.	57.0	Adopted by small scale pig farm owners. Cannot be used in backyard production system due to high cost investment.

Productivity and production of crossbred pigs: The study revealed productive performance was highest in two-breed cross of pigs with 75% H inheritance (HN-75) and three-breed cross (HND) pigs (Table 2). Reproductive performance included ages at puberty, first conception and first farrowing, along with inter-farrowing interval, pregnancy and farrowing rate as well as litter performance. The HN-75 was found to be having shorter inter-farrowing interval and higher pregnancy rate than other genetic groups. Regarding carcass traits, three-b cross had a higher dressing percentage and less back-fat thick than other crossbred pigs. Two breed crosses of pigs were foun be having a higher back-fat thickness than three-breed cross and HN-75 had a better dressing percentage than HN-50. Thu was concluded that three breed cross was recommended for meat production, and two-breed cross HN-75 was recommen for both breeding and fattening purposes for subtropical Eas Himalayan hilly climate (Kadirvel et al. 2021a).

Table 2. Productive and reproductive traits in different categories of pigs

Productive traits	**Indigenous pig (NM)**	**Two breed crossed (HN-75%)**	**Three breed crossed (HND)**
Body Weight at different ages (kg)			
2 months	$5.87^{a} \pm 0.34$	$8.73^{b} \pm 0.42$	$9.10^{b} \pm 0.44$
6 months	$22.19^{a} \pm 1.43$	$37.13^{b} \pm 1.24$	$41.30^{b} \pm 1.13$
8 months	$41.74^{a} \pm 1.12$	$61.30^{b} \pm 1.18$	$62.65^{b} \pm 1.23$
Reproductive traits			
Litter Size at birth (no.)	$6.86^{a} \pm 0.58$	$8.87^{b} \pm 0.34$	9.82 ± 0.21
Litter Size at weaning (no.)	$5.53^{a} \pm 0.53$	$8.23^{b} \pm 0.04$	8.53 ± 0.43
Litter weight at birth (kg)	$3.97^{a} \pm 0.45$	$8.43^{b} \pm 0.38$	$9.54^{c} \pm 0.28$

Avg. Litter weight at weaning (kg)	5.96^{a}±0.39	9.24^{b} ±0.17	9.84^{c}±0.75
Av. weaning percentage (%)	86.70^{a}±0.78	94.23^{b} ±0.17	85.4^{c}± 0.72

Means with different superscripts differed significantly between rows (P < 0.05).

Artificial Insemination:

A total of 167 estrus sow/gilts were artificially inseminated, and a farrowing rate of 78.44 % was obtained with a mean litter size of 7.86±0.65 following AI, which did not differ significantly from natural service. However, the growth rate of crossbred piglets obtained through AI was significantly higher than the growth rate of piglets born out of natural service. The tribal farmers were benefited by AI in several ways: (1) timely availability of superior germplasm to produce crossbred piglets; (2) saved the mating cost of INR 1,000–1,200 and transport of cost (INR 300–400) of female to the boar premises and (3) controlled mating to prevent inbreeding (Kadirvel *et al.,* 2013). The present study clearly demonstrates the feasibility and potential benefit of AI technique to smallholder backyard pig production system in tribal rural areas. In addition to genetic improvement of nondescript local pigs, this technology can help in overcoming breeding constraints in smallholder backyard pig production for increasing productivity. (4) Employment generation: Potential unemployed educated youths are identified and trained for semen collection, processing and insemination, so that they can become inseminator and generate income for their livelihood. (5) Spin off effect: After seeing the results/benefits of the AI technology, other tribal farmers from other villages have shown interest and adopted AI technology in pig for breeding purpose (Kadirvel *et al.*, 2021a).

Innovative integrated low-cost pigpen:

The pig housing model was evaluated and compared with conventional concrete floor pig housing in term of micro-environment, physiological adaption, performance, water use efficiency, animal welfare and behaviour. The results revealed that the temperature and humidity of the developed pigpen maintain within the normal range as compared to the conventional concrete pigpen during winter as well as rainy season. In winter, temperature of conventional concrete pigpen recorded average of 62.7ºFand floor temperature was 56.3°F. The low temperature in the conventional concrete pen causes stress and energy loss to the pigs during winter. However, the saw dust-floor in developed pigpen provided warm and comfortable environment to pigs. In rainy and summer season, the conventional pigpen has always wet floor and recorded significantly (P<0.01) higher humidity and temperature-humidity index (THI) as compared the developed pen, which causes stress to the pigs. The body weight at different stage of age and disease incidence is presented in Table.3

Table 3. Body weight and disease incidence in different housing system

Parameters	Developed model	Concrete floor
Body weights		
3 months	9.75 kg	9.36 kg
6 months	64.56 kg	56.83 kg
9 months	106.83 kg	76.28 kg
Average daily weight gain	545.5 g	386.7g
Disease conditions		
Leg problem	Nil	6.6%
Skin disease	Nil	4.7%
Diarrhea	Nil	10.2%
Respiratory problem	Nil	2.8%
Mortality	Nil	1.82%

There is a huge potential for the technology in the north eastern region of India, where pig population is very high. Since this model suitable to mid and high altitude region, demand of the technology is high in the hill ecosystem where enough wood and bamboo is available. The manure production in the developed pen and the conventional concrete pen was 4,100 and 1,460 kg, respectively. The manure production in the developed pen has 2-3 times higher as compared the conventional concrete pen.

Deworming and vaccination: Regular deworming and vaccination against classical swine fever was carried out. The mortality percentage recorded before and after the implementation of the technology. The pre-weaning pig mortality reduced from 15 to 20 percent and 7 to 8 percent and the growers mortality reduced from 10 to 15 percent to 5 to 8 percent.

Vermi-compost: This pig house model was also integrated with vermin-compost unit. A total of 10 numbers of vermicomposting unit of 10 x 3 x 2 ft were constructed with low cost fabricated tanks along with thatch roof and 15 kg of earthworm culture was released @ 1.5 kg per tank for supplementation of organic manure and efficient use of available bio mass and crop residues etc., subsequently, enhancing carbon cycling. Awareness increased to 90% about vermin-compost production and about 4 tonnes composts already produced to meet 20 kitchen gardens requirement. Similarly, Iria Villar *et al.* (2017) also reported the use of vermi-compost from pig manure.

Pig shed Water recycling: The recycling model unit consisted of five stages viz., physical screening, sedimentation unit and alum treatment, filtration tanks 1 and 2, followed by chlorination in the final storage tank. The water quality before and after the treatment were analysed to find out the efficacy of filtration process. Parameters analysed were pH, total dissolved solids (TDS), colour, turbidity, total plate count (TPC), Coliform, faecal streptococci, 5-day Biological Oxygen Demand (BOD5) and dissolved oxygen (DO). Results from the present study indicated that the recycled water is fit for reuse in agriculture as well as cleaning of the pig sheds. The model was found to be an effective and efficient method for recycling of wastewater and preventing the environmental population from the pig sheds in the north-eastern hill region. This model is useful especially during water scarcity in the winter season. This model has been demonstrated in 37 pig breeding farms and farmers is satisfied with the model (Kadirvel *et al.,* 2021b). Various researchers have reported wastewater treatment in pig farms (Olanrewaju and Olowoyeye, 2018 and Velho et al. 2012).

Livelihood enhancement: Livelihood enhancement of the farmers depended on the improvement of their socio-economic status, way of living, possession of materials, assets including knowledge and skill level. After 4 years of training and demonstration of crossbred pig with improved management practices, livelihood of tribal farmers assessed using different components (physical capital, natural capital, human capital, financial capital and social capital) in the study. Although there was slight significant difference observed before and after technological demonstration in term of physical and natural assets, however, there was a significant improvement in social, financial and human capital after the implementation of training and demonstration. The significant improvement may be due to increased income, participation, social interaction, mobility and nutritional security of selected tribal farmers. Similarly, there was significant increase in financial capital after 4 years of the implementation of training and demonstration. The livelihood index value and total capital value increases from 0.572 to 0.766 and 2.863 to 3.834 respectively after implementation of training and demonstration for selected farmers. (Table 4). The study indicated that with improved pig management practice, there was an increase in income and livelihood of the tribal farmers.

Nutritional improvement:
The average intake of vegetables, cereals, meat, egg and numbers of meals per day was assessed and recorded before and after the intervention. The values for per person per month is presented in Table 5. From the table we can appreciate that all the parameters increased after the intervention in comparison to before the intervention. There is better nutritional accessibility and availability among the tribal pig farmers after the intervention.

4. Conclusion

The study concluded that the technologies related for pig husbandry leads to improvement in productivity, income and livelihood of tribal farmers in the study area. There was better nutritional accessibility and availability among the tribal pig farmers after the intervention. The tribal farmers obtained two-fold increase in income from rearing of crossbred pigs as compared to rearing of local pig and by adopting different technologies developed for them.

Table 4. Different livelihood capital index values in study area (before and after technological intervention)

Assets/Capital	Before	After
Human Capital Index	2.44315	3.0089
Natural Capital Index	1.355	1.80625
Financial Capital Index	4.92875	5.785
Physical Capital Index	2.1135	2.49875
Social Capital Index	3.475	6.075
Total Capital Value	2.86308	3.83478
Livelihood Index Value	0.572616	0.766956

Table 5. Food availability before and after intervention (average intake per person per month)

Particulars	Before	After
Vegetable (green leaves) (kg)	1.5	2.7
Cereals (kg)	13.8	18.9
Meat (kg)	1.85	2.44
Eggs (nos)	11.28	22.2
No. of meals /day	2.3	2.9
Duration of storage of food-grain (months)	3.7	6.8
Household having food-grain storage facility (%)	32.3	54.4

5. References:

Dutta S. and SK Guchhait (2018). Measurement of Livelihood Assets in Sustainable Forest Governance: A Study in Burdwan Forest Division, West Bengal. Transactions of the Institute of Indian Geographers 40(2): 203-216.

Iria V, David A, and M Salustiano (2017). Product quality and microbial dynamics during vermicomposting and maturation of compost from pig manure. Waste Management. 69:498-507. Doi:10.1016/j.wasteman.2017.08.031

Kadirvel G, Devi YS, Khargharia, G, Marak, TB, and S Deori (2021b). Pig shed wastewater recycling model for smallholder pig production system of Northeast Himalayan Region. International Journal of Livestock Research 11 (1): 172-176.

Kadirvel G, Devi YS, Singh LA, Singh NM, Baruah KK, and BK Kandpal (2021). Productive and reproductive performances of two-breed and three-breed pig crosses with Niang Megha, Hampshire and Duroc inheritance reared under subtropical Eastern Himalayan hilly climate. Tropical Animal Health and Production 53: 1-9.

Kadirvel G, Kumaresan A, Bujarbaruah KM, Venkatasubramanian V, Das A, and SV Ngachan (2013). Artificial insemination of pigs reared under smallholder production system in North-Eastern India: success rate, genetic improvement, and monetary benefit. Tropical Animal Health Production 45(2):679–686.

Kadirvel G, Kumaresan A, Das A, Bujarbaruah KM, Venkatasubramanian V, and SV Ngachan (2013). Artificial insemination of pigs reared under smallholder production system in northeastern India: success rate, genetic improvement, and monetary benefit. Tropical Animal Health and Production 45:679–686. doi: 10.1007/s11250-012-0277-z

Kath K, Rahman S, Das S, Chaudhar J, Goswami R, Tochhawng L. and B Chutia (2019). Socio-economic status of Tenyi- Vo Pig Farmers of Nagaland, India. International Journal Livestock Research 9(11):196-203.

Majunder KP, Harikrishna C, Chandra AS, and M Venkateswarlu (2020). A study on swine management practices in Telangana state. The Pharma Innovation Journal 9(3): 509-519.

Moanaro, Ngullie E, Walling I, Krose M, and BP Bhatt (2011). Traditional animal husbandry practices in tribal states of Eastern Himalaya, India: a case study. Indian Journal of Animal Nutrition 28(1):23-28.

Muangkae, T, and GP Shivakoti (2005). Effect of livelihood assets on rice productivity: case study of rice-based farming in Southern Thailand. ISSAAS Journal 11: 63–83

Olanrewaju OO, and OS Olowoyeye (2018). Treatment and Recycling of Wastewater from Selected Piggery in Futa Community. International Journal of Engineering Science and Application, 2(3): 106-112.

Shyam J, Borgohain A, and D Talukdar (2017). Management practices and constraints perceived by piggery farmers in Kamrup district of Assam. Indian Journal of Social Research 58 (1):65-70.

Talukdar P, Samanta G. and GD Rao, (2019). Swine feeding and rearing practices in the Peren district of Nagaland, India. Journal of Entomology and Zoology Studies 7(2):561-565.

Velho, VF, Mohedano RA, Belli Filho P, and RH Costa (2012). The viability of treated piggery wastewater for reuse in agricultural irrigation. International Journal of Recycling of Organic Waste in Agriculture, 1(1): 10.