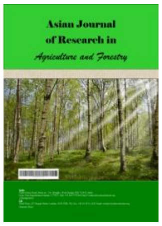

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Meta-analysis of Technical Efficiency in Selected Agricultural Sub-sectors: Implications for Policy Making in Developing Countries like Sri Lanka

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Authors' contributions

This work was carried out in collaboration among all authors. Authors CKB, GDKK and ADP designed the study concept. All authors managed to collect and included important literature to the manuscript. The first draft was written by CKB, ADP and SMPS. SMPS, MHSMH and RPWAD prepared the tables, figures, reference list and formatted them. In addition, authors GDKK and ADP fine-tuned the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate the technical efficiency (TE) in selected agricultural sub-sectors and to propose possible policy interventions to the government with the aim of reducing the poverty of farmers in the developing world.
Study design: A meta-analysis based on empirical studies conducted by various scientists throughout the developing world.
Methodology: Research articles for the meta-analysis were selected using a thorough screening process based on the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) concept. Selected 94 articles were sub-divided in to three main agriculture sub-sectors for detailed analysis; (a) paddy, other field crops-OFC and vegetables, (b) fruits, and (c) livestock.

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Mean TE of each crop or livestock type was calculated by averaging the TE values for a particular crop or livestock type across different studies included in this study.

Results: TE data presented in the original articles showed a considerable dispersion within a given study. The highest mean TE was recorded in B-onion (0.83±0.15) whereas the lowest was recorded in maize (0.703±0.09) and in soybean (0.705±0.13). The TE of chili cultivation was 0.78 with the greatest variability (standard error of mean [SEM] 0.19) among the crops considered, which signifies the unpredictable nature of the chili cultivation. Mango was found to be the least technically efficient crop among the studied, with a mean TE of 0.596±0.11. Dairy, poultry and aquaculture farming operations were found to be highly technically efficient having mean TE values of 0.80±0.16, 0.89±0.02 and 0.88±0.08 respectively.

Conclusion: Findings of this study will lead to several key policy implications including, improvement of the socioeconomic characteristics of farmers, implementation of farmer field schools (FFS) and establishment of a cautious and gradual strategy for expansion of the rural financial institutions.

Keywords: Agricultural Technical Efficiency (TE); Meta-analysis; policy implications; PRISMA.

1. INTRODUCTION

Agriculture plays a vital role in the economy of the developing world. It contributes to the economic growth of countries in varying magnitudes. More so in developing countries compared to developed countries [1]. The contribution of agriculture to the sustainable economic development lies with its ability to alleviate poverty, ensure food security and to improve the rural economy gradually [2].

Overtime, contribution of agriculture to the GDP growth of countries has declined [2]. It has also led to the poverty of farmers in the developing world. In order to rejuvenate agriculture and to reduce the poverty of farmers, production efficiencies in different agricultural subsectors needs to be optimized and government-controlled policy interventions are necessary. Hence the evaluation of the productivity and performance of agricultural sub sectors becomes utmost important.

Numerous researchers have put forward various qualitative and quantitative ideas to measure the performance of agricultural sub sectors and to optimize income generation in the smallholder sector. In determining performance, technical efficiency (TE) is one of the most effective measurement available. Technical efficiency (TE) is generally defined as the ability of a decision-making unit (i.e. a farm) to produce maximum output given a set of inputs and technology [3]. It provides the means for developing new technologies and ideas which permit low input costs and low power-consuming inputs in farming.

According to [4], TE is one component of economic efficiency (EE) where the latter is defined as the product of TE and allocative efficiency (AE), which is still considered as an accepted explanation. In turn, AE refers to the ability to produce a given level of output using cost-minimizing input ratios. In the present study, the research team has taken only the TE into consideration as it directly relates the inputs to outputs in a more tangible sense.

[5] has defined two measures of TE; the first one being the output-oriented Timmer-type measure, which relates actual output to best practice output. It gives the maximum amount by which output can be increased for a given input vector. The second measure is the Farrell-type measure which is input-oriented, reflecting the ratio of best practice input usage to actual input usage, while output held constant. It gives the maximum amount by which an input vector can be decreased proportionally, while producing the same amount of output. Moreover, the input-oriented measure has an intuitive cost interpretation since one minus the degree of TE gives the percentage decrease in total cost associated with the complete removal of technical inefficiency [5].

The TE value for multiple input and output variables can be estimated by the ratio of the weighted sum of outputs to the weighted sum of inputs. Mathematically, it can be expressed as follows [6].

$$TE = \frac{u_1\,y_{1j} + u_2\,y_{2j} + \cdots + u_{\mathrm{n}}\,y_{nj}}{v_1\,x_{1j} + v_2\,x_{2j} + \cdots + v_{\mathrm{m}}x_{mj}} = \frac{\sum_{r=1}^{n} u_{\mathrm{r}}\,y_{rj}}{\sum_{s=1}^{m} v_{\mathrm{s}}\,x_{sj}}$$

Where, u_r indicates the output weight n, y_r indicates the output quantity n, v_s indicates the input weight n, x_s indicates the input quantity n, r indicates the number of outputs (r = 1, 2, …, n), s indicates the number of inputs (s = 1, 2, …, m) and j indicates the j^{th} decision making unit (DMU) (j = 1, 2, …, k). If any parameter is missing here, the TE value cannot be estimated for a given crop, even though approximation methods have been used elsewhere.

The objective of this study was to evaluate the TE in selected agricultural sub-sectors using empirical studies conducted by various scientists in the developing world, and to propose possible policy interventions to the policy makers.

2. METHODOLOGY

The focus of the research team on the meta-analysis of TE was purely based on the empirical studies conducted by various researchers in the developing world.

Even though the documents carrying TE estimated through Deterministic production frontiers that include parametric and non-parametric frontiers, and through Stochastic production frontiers that include cross-sectional frontiers, panel data and dual frontiers were gathered at the pre-screening stage, the documents with Stochastic-production-frontier approach were selected to study the TE further. The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) concept is applied in the document to illustrate the methodology in detail (Fig. 1).

The 94 articles selected for the study were sub-divided in to three main agriculture sub-sectors for detailed analysis; (a) paddy, other field crops-OFC and vegetables, (b) fruits, and (c) livestock. A forest plot carrying the mean TE was generated for all three sub-sectors taking individual crop or livestock-type into consideration where more than five articles were available. Though evidences were not sufficient (n=3), aquaculture was also taken into the forest plot considering the importance of that sector. Mean TE of each crop or livestock type was calculated by averaging the TE values for a particular crop or livestock type across different studies included in this study.

3. RESULTS AND DISCUSSION

The mean TE of each study is presented in the Table 1. It is apparent that the TE of different crops in different regions in the world vary greatly. The TE of the same crop varies with the way that the resource allocation takes place even within a given country. However, the TE data presented in the original articles show a considerable dispersion within a given study, in some cases dispersed in the range from 0.2 (min) to 0.9 (max). Of the 94 studies considered, only 47 studies have yielded a TE of above 0.8, where livestock sector stands out predominantly (poultry, dairy and aquaculture). Among the major crops belong to this category, cucumber and B-onion dominate.

Fig. 2. shows the forest-plot carrying the mean technical efficiencies for the crops considered and for the livestock sub-sector, based on the means calculated for each crop/livestock sub-sector using the 94 articles presented here. Apart from paddy, of the key crops considered in the present study, i.e. maize, potato, soybean, chilli and B-onion, the highest mean TE was recorded in B-onion (0.83±0.15) whereas the lowest was recorded in maize (0.703±0.09) and in soybean (0.705±0.13) [7-26]. The TE of chilli cultivation was 0.78 with the greatest variability (standard error of mean [SEM] 0.19) among those crops, that signifies the unpredictable nature of the chilli cultivation [27-31].

Among all the crops considered in the present study, cucumber seems to be a highly technically efficient crop (Fig. 2), with a mean TE of 0.88±0.07 [32-36]. Tomato cultivation was also technically efficient (0.80±0.08) considerably [37-40]. Vegetables, in general, displayed approximately 34% of the technical inefficiencies [41-45].

Among the fruit crops studied in the meta-analysis, citrus and grapes resulted in an estimated mean TE of 0.78±0.05 and 0.77±0.08 respectively [46-51]. Mango was found to be the least technically efficient crop among the studied, with a mean TE of 0.596±0.11 [52]. Pineapple is the most unpredictable crop among the fruits studied resulting an average TE of 0.67 with a standard error of 0.25 [53-57].

Dairy, poultry and aquaculture farming operations were found to be highly technically efficient having mean TE values of 0.80±0.16, 0.89±0.02 and 0.88±0.08 respectively. Among these three activities, the TE of poultry can be highly predictable, with a minimal dispersion of error, whereas the most unpredictable venture being the dairy [58-71].

As per the results of this study, the broad differences in the technical efficiencies show that there is a need for awareness among farmers to operate the farming technique, appropriately. Technological awareness in operating farms is necessary to optimize a farmer's income [72]. Definite governmental authorities and private sectors could help in minimizing of input costs to obtain output gains.

Many previous studies indicate that the farmer's education level and farming experience have significant positive effects on TE. Further, the wasteful uses of production costs by inefficient farmers have also been reported. In addition, age of the farmer, access to credit and extension facilities, scale of operation, fragmented structure of farmlands, off-farm income and membership in a cooperative society are amongst the other factors that affect the TE of a given farm [73-76].

One of the key observations of the research team in relation to TE is that, sufficient studies have been conducted to estimate the TE in paddy farming around the world [77-87,76,88,89]. However, the attention paid on estimating TE of other crops is not satisfactory, perhaps due to the fragmented smallholder farm sizes and unavailability of reliable data, as the research team also experienced in its own farmer survey (data not shown). With some effort, the research team tried to include TE studies conducted in Sri Lanka in relation to agriculture sector, however, again the hindrance was the lack of recent studies. Nevertheless, the current meta-analysis includes 11 Sri Lankan studies related to TE in agriculture sector (Table 1). Lack of recent, global studies conducted on the TE of crops barring paddy, and lack of recent, local (Sri Lankan) studies conducted on the TE of crops were the biggest limitations faced during this study.

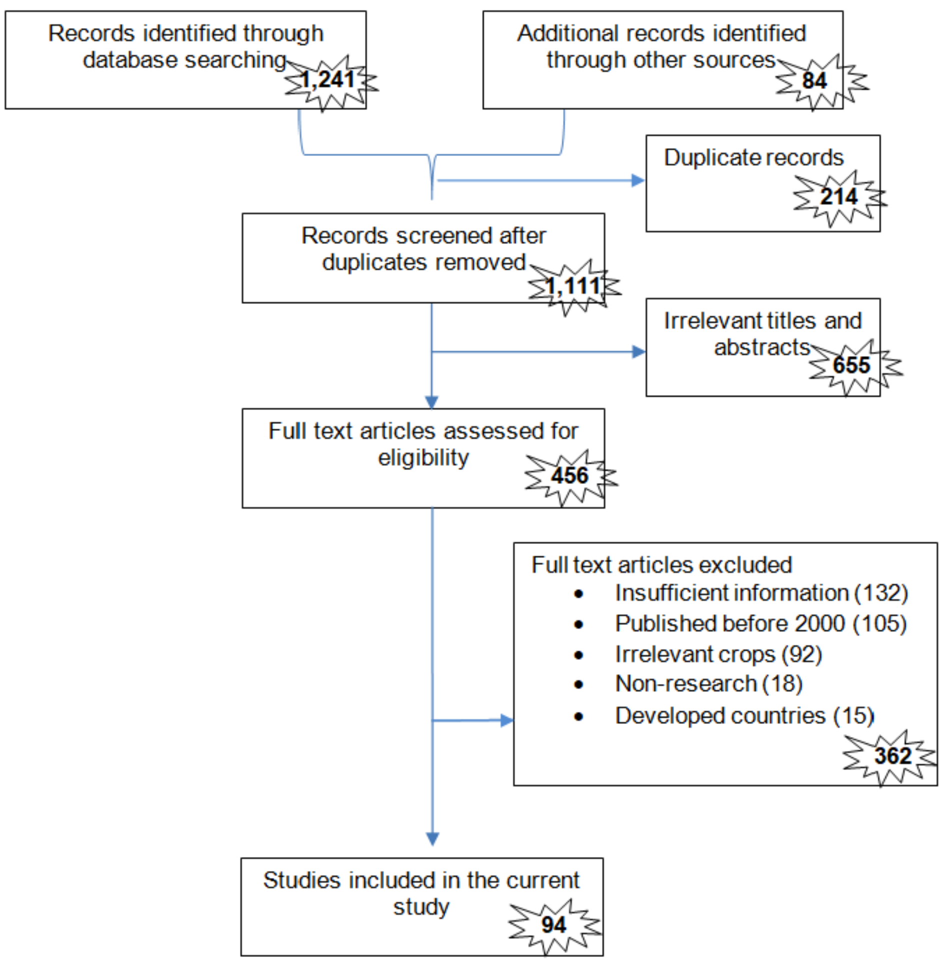

Fig. 1. PRISMA (Preferred Reporting Items for Systematic reviews and Meta-analyses) flow diagram of included articles in the Technical Efficiency (TE) of resource allocation

Table 1. Technical efficiencies of three agriculture sub-sectors

a) Paddy, OFCs and Vegetables

Author	Country	Journal	Sample Size	Mean TE
Rice/Paddy				
[77]	Bangladesh	*Applied Economics*	295	0.59
[79]	India	*Energy Conversion and Management*	97	0.77
[80]	Nepal	*The Australian Journal of Agricultural and Resource Economics*	76	0.76
[94]	Vietnam	*Agricultural and Food Economics*	1,000	0.65
[95]	Vietnam	*International Journal of Development Issues*	595	0.70
[96]	Malaysia	*American Institute of Physics*	70	0.61
[82]	Korea	*The Australian Journal of Agricultural and Resource Economics*	5,130	0.72
[84]	Iran	*Journal of Cleaner Production*	82	0.8
[85]	Iran	*Engineering in Agriculture, Environment and Food*	120	0.79
[86]	Iran	*Journal of Cleaner Production*	240	0.95
[76]	Turkey	*New Zealand Journal of Crop and Horticultural Science*	70	0.92
[78]	Sri Lanka	*Sri Lanka Economic Research Conference*	100	0.73
[89]	Sri Lanka	*Research Reports - HARTI*	495	0.72
[81]	Sri Lanka	*Journal of Agricultural Economics*	460	0.72
[87]	Sri Lanka	*Australian Journal of Basic and Applied Sciences*	357	0.73
Maize				
[15]	Iran	*Energy*	89	0.55
[11]	Iran	*Energy*	10	0.81
[7]	Ghana	*African Journal of Agricultural Research*	360	0.74
[10]	Nigeria	*Journal of Development and Agricultural Economics*	100	0.69
[13]	Sri Lanka	*Mediterranean Journal of Social Sciences*	130	0.72
Potato				
[16]	Uzbekistan	*Agriculture*	178	0.64
[18]	Iran	*Information Processing in Agriculture*	23	0.9
[24]	Iran	*International Journal of Green Energy*	44	0.74
[25]	Sri Lanka	*Sri Lanka Journal of Economic Research*	100	0.73
[9]	Sri Lanka	*Tropical Agricultural Research*	55	0.72
Soybean				
[21]	Iran	*Journal of Cleaner Production*	94	0.81
[22]	Iran	*Applied Energy*	94	0.85

[14]	Ghana	*Sustainable Agriculture Research*	200	0.53
[20]	Ghana	*ADRRI Journal of Agriculture and Food Sciences*	168	0.61
[26]	India	*Soybean Research*	200	0.72
Chili				
[29]	Bangladesh	*American Journal of Applied Sciences*	100	0.77
[28]	Bangladesh	*Journal of Statistics Applications & Probability Letters*	50	0.88
[30]	Thailand	*91st Annual Conference of the Agricultural Economics Society*	107	0.45
[27]	Indonesia	*Proceedings of 2nd International Conference on Food and Agriculture*	125	0.86
[31]	Indonesia	*International Journal of Progressive Sciences and Technologies*	30	0.94
B-Onion				
[12]	Bangladesh	*Bangladesh Journal of Agricultural Research*	225	0.83
[17]	Pakistan	*Journal for the Advancement of Developing Economies*	93	0.94
[110]	Ethiopia	*International Journal of Agricultural Extension and Rural Development*	100	0.82
[19]	Pakistan	*The Pakistan Development Review*	60	0.59
[23]	Indonesia	*Entomology and Applied Science Letters*	75	0.98
Tomato				
[38]	India	*Agricultural Economics Research Review*	90	0.78
[40]	Iran	*Information Processing in Agriculture*	150	0.92
[39]	Iran	*Energy*	31	0.82
[37]	Ghana	*American Journal of Experimental Agriculture*	100	0.71
[38]	India	*Agricultural Economics Research Review*	90	0.78
Vegetable crops				
[45]	India	*Indian Journal of Science and Technology*	270	0.57
[41]	Sri Lanka	*Sri Lanka Journal of Economic Research*	450	0.52
[43]	Sri Lanka	*Sri Lanka Journal of Economic Research*	243	0.75
[44]	Sri Lanka	*Journal of Management and Tourism Research*	50	0.79
[42]	Tanzania	*Journal of Development and Agricultural Economics*	181	0.67
Cucumber				
[32]	Iran	*Journal of Cleaner Production*	60	0.87
[34]	Iran	*Energy*	26	0.99
[33]	Iran	*Expert Systems with Applications*	46	0.82
[35]	Iran	*Energy Conversion and Management*	18	0.88
[36]	Iran	*Journal of Agricultural Science and Technology*	26	0.83

b) Fruits

Author	Country	Journal	Sample Size	Mean TE
Watermelon				
[97]	Iran	*International Journal of Renewable Energy Research*	85	0.67
[111]	Iran	*Journal of Cleaner Production*	88	0.80
[98]	Bangladesh	*IOSR Journal of Economics and Finance*	180	0.86
[99]	Indonesia	*International Journal of Computer Applications*	169	0.64
[100]	Nigeria	*International Journal of Applied Agricultural and Apicultural Research*	80	0.65
Citrus				
[46]	Spain	*Agricultural Systems*	100	0.71
[47]	Brazil	*Bio-based and Applied Economics*	67	0.79
[50]	Iran	*Journal of Cleaner Production*	60	0.90
[51]	Spain	*Agricultural Systems*	33	0.71
Pineapple				
[101]	Malaysia	*American Journal of Applied Sciences*	124	0.29
[54]	Sri Lanka	*Journal of Food and Agriculture*	80	0.85
[55]	Nigeria	*International Journal of Fruit Science*	101	0.61
[56]	Indonesia	*IOSR Journal of Agriculture and Veterinary Science*	142	0.70
[53]	Nigeria	*Agris on-line Papers in Economics and Informatics*	120	0.93
Mango				
[52]	Vietnam	*International Journal of Multidisciplinary Research*	1613	0.53
[102]	Myanmar	*Journal of the International Society for Southeast Asian Agricultural Sciences*	151	0.71
[103]	Vietnam	*International Journal of Environmental & Agriculture Research*	741	0.43
[112]	India	*International Journal of Current Microbiology and Applied Sciences*	50	0.66
Grape				
[104]	Iran	*Energy*	41	0.72
[105]	Spain	*Journal of Cleaner Production*	40	0.86
[49]	Tanzania	*Rural Planning Journal*	126	0.77
[106]	China	*International Conference on Education, Sports, Arts and Management Engineering*	1690	0.77

c) Livestock

Author	Country	Journal	Sample Size	Mean TE
Broiler and Poultry				
[58]	Iran	*Information Processing in Agriculture*	70	0.88
[68]	Iran	*Energy*	90	0.91
[59]	Bangladesh	*Applied Economics*	75	0.86
[64]	Iran	*Brazilian Journal of Poultry Science*	44	0.92
[107]	Nigeria	*International Journal of Poultry Science*	49	0.87
Dairy farm				
[60]	Turkey	*Journal of Applied Animal Research*	80	0.95
[62]	Africa	*Agrekon*	371	0.80
[63]	Turkey	*Journal of Applied Animal Research*	87	0.61
[65]	Iran	*Energy*	30	0.93
[108]	Iran	*Journal of the Saudi Society of Agricultural Sciences*	110	0.90
[109]	Spain	*Science of the Total Environment*	72	0.43
[67]	Ireland	*Irish Journal of Agricultural and Food Research*	190	0.83
[69]	Scotland	*Ecological Indicators*	200	0.82
[70]	Germany	*Agricultural Systems*	216	0.83
Aquaculture				
[61]	Turkey	*Aquaculture*	73	0.82
[66]	Malaysia	*Aquaculture Reports*	100	0.86
[71]	China	*Aquaculture Economics & Management*	48	0.97

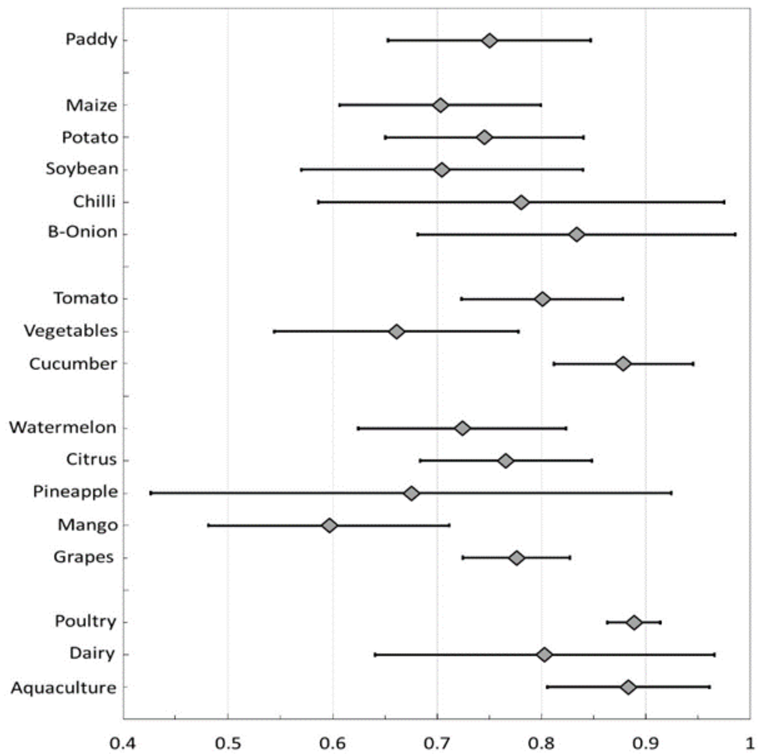

Fig. 2. Forest-plot of mean Technical Efficiencies (TE) of different agricultural sub-sectors. Mean and the Standard error of the mean is given. n≥5 for each sub-sector except for Aquaculture (n=3)

From a policy standpoint, more accurate TE estimates are crucial in guiding policy decisions dealing with farm extension and training programs, among others. As implications of the study findings for future research, further meta-analysis research of TE seems warranted. In our opinion, additional work that incorporates a larger set of studies with broader geographical and or sectoral coverage would produce a better understanding of the association between measures of TE and the attributes of the studies reporting these measures. Moreover, the researchers should be encouraged to perform more and more studies related to TE of agriculture sub-sectors within Sri Lanka.

4. CONCLUSION

The findings of the meta-analysis of TE will lead to several key policy implications, summarized below;

A) in order to enhance productivity, there is a need to emphasize improvement of the socioeconomic characteristics of farmers. Since education levels significantly influence output, the focus should be on better training for the farmers and on encouraging the use of better farm inputs. This would discourage the farmers' misbeliefs if any. Training of farmers can be intensified by increased extension services via demonstration farms within the vicinity of most farmers.

B) in recent years, a number of development agencies, including the world bank, have promoted farmer field schools (FFS) as a more effective approach to extend science-based knowledge and practices. The FFS training program utilizes participatory methods ‘‘to help farmers develop their analytical skills, critical thinking, and creativity, and help them learn to make better decisions’’ [90]. Such an approach, in which the trainer is more of a facilitator than an instructor, reflects a paradigm shift in extension work [91]. As an extension approach, the FFS concept does not require that all farmers attend FFS training. Rather, only a selected number within a village or local farmer group are trained in these informal schools. However, in order to disseminate new knowledge more rapidly, selected farmers receive additional training to become farmer-trainers, and are expected to organize field school replications within the community, with some support from public sources. These farmer-to-farmer diffusion effects are expected to bring about cost-effective knowledge dissemination and financial sustainability, issues that have hampered many public extension systems in developed and developing countries [92,93].

C) given that the necessary complementary resources and economic environment are not yet in place for access to formal credit for smallholder rural population in Sri Lanka, and considering that the formation of sustainable rural financial institutions is such a difficult task in poor rural economies, the research team recommends a cautious and gradual strategy for expansion of the rural financial institutions in the farming communities. This strategy would require direct support by the government, through an adequate legal and regulatory framework, of institutional innovations and pilot programs in rural areas that may have the potential to reduce transaction costs in providing savings, credit, and insurance services to the rural clientele. In achieving the same objective, this can be done through farmers' cooperatives and other organizations at the local level.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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