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CONTENTS

Food & Health

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Environment

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Journal of Food, Agriculture & Environment Vol.12 (1): 238-247. 2014 *www.world-food.net*

Cluster analysis for classification of farm households based on socio-economic characteristics for technology adoption in agriculture: A case study of West Java province, Indonesia

Nita Kuswardhani [1, 2], Peeyush Soni [1]* and Ganesh P. Shivakoti [1]
[1] *Agricultural Systems and Engineering, Asian Institute of Technology, Thailand.* [2] *Agricultural Technology Faculty, Jember University, Indonesia. e-mail: soni@ait.asia, soni.ait@gmail.com, nkuswardhani@gmail.com, ganesh@ait.ac.th*

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Abstract

Blind drive of intensifying vegetable production to combat issues of low productivity, low quality of product and ensuring off season availability of vegetables, pose serious challenges for smallholder farmers to adopt efficient and appropriate technologies. Technology adoption is a complex process depending on several factors mainly including the socio-economic status of individual farmers. The differentiation on adopting technology could be explained by farm typology. The aim of this research was to classify groups of farm households in the West Java Province of Indonesia based on identification of factors influencing new technology adoption. A survey of farmers was carried out during January-December 2010 in Sukabumi (medium and highland) and West Bandung regency (highland). The information obtained through the survey was analysed using multivariate analysis, which was carried out through Principle Component Analysis (PCA) and Cluster Analysis (CA) to classify the farm households based on socio-economic characteristics. Selected variables derived from questionnaires were used to describe the components that influence the adoption of agricultural technology and to identify the group of potential farmers. The results indicate that the farmers could be classified into three, four, and two groups of typical farm households in medium land Sukabumi Regency, highland Sukabumi Regency, and West Bandung Regency of West Java Province, respectively.

Key words: Technology adoption, farm household, farm typology, multivariate analysis, Sukabumi regency, West Bandung regency.

Introduction

One of the most important strategies in economic growth is the development of the agricultural sector. The agricultural sector is a major source of livelihood for most Indonesians, and as a source producer for considerable foreign exchange. Agriculture contributes 14.7% of Gross Domestic Product (GDP) in Indonesia [1]. Even though this sector is a small share of GDP, it is still regarded as one of the most important sectors in terms of providing employment. In many developing countries including Indonesia, it is a concern to extend the horticultural production base as it could contribute to agricultural development, diversity of agriculture, and opportunity of employment. The government of Indonesia is re-defining the expansion of horticultural production into the establishment of agribusiness and agroindustry system [2]. The main goals in horticultural agribusiness are to succeed in primary horticultural producer/participation of farmers in the local market and to enhance economic performance and livelihood, and to build strong relationships between farmers and the private sector, especially the trading and retailing sector.

West Java Province, especially in Sukabumi and West Bandung regency, is one of the important provinces that produce notable amounts of horticultural products including vegetables, because of its favourable climate and fertile land. This province has potential to increase horticultural production by introducing appropriate new technologies to the farmers. With an aim of expanding the horticultural production in Indonesia, protected cultivation, as a new adoption technology has been introduced in the West Java Province. However, the promoted technology has not grown rapidly mainly due to socio-economic circumstances. So far, no study has been reported to analyse the underlying situation into farm household profile with relation to the adoption of new technology in this province. Differences in adoption could be highlighted by farm typology.

It is known that promoted new technology for farmers has to be matched with socio-economic circumstances. Different socio-economic characters among farm households may result varied levels of motivation in accepting new technology [3-10]. The income and utility models are also the important determinants in technology adoption for an economic paradigm [11]. Cary and Wilkinson [12] mentioned that in the income paradigm, farmers are profit maximisers and the technology that increases net returns will be adopted. Meanwhile, the utility paradigm asserts that farmers adopt technology basically due to utility maximisation rather than profit maximisation [13, 14]. In the utility paradigm, a producer responds to many factors besides income, including non-income factors, such as environmental quality, social benefit, and/or altruism. Bultena and Hoiberg [15] used risk orientation, perceived erosion and perceived attitudes of other farmers, as well as their perception of other farmers' adoption to explain the adoption of conservation practices. Some researchers had provided evidence that availability of information to producers, and the level of education and experience of prospective adopters, are better determinants for adoption of new practices than income [14]. Technology adoption has been a major part of the agricultural research agenda for economists and sociologists for several decades [16-19].

Developing typology is an important step in any realistic evaluation of the constraints and opportunities that occur within farm households [20]. Therefore, typology studies may be employed for researching factors that explain the adoption of new technology. The Commission on Agricultural Typology was constituted with the task of determining common principles, criteria, methods and techniques for agricultural typication, and to specify the typological and regional classication of world agriculture [21]. When the detail database is available, multivariate statistical techniques permit us to find such typologies. A combination of Principal Component Analysis and Cluster Analysis for reducing the number of variables had been followed in identifying the typical farm households by several researches [22-28].

The purpose of this study was to present the important factors related to adopt greenhouse technology in West Java and followed by the typology analysis of farm households. Different types of farm household were used to explain the most crucial factors in understanding and determining the group-specific problems and opportunities in adoption of new technology. In this research, adoption of protected cultivation farming was considered as a new technology that enables continuity in production throughout the year, resulting in a more evenly spread labour demand and a higher farmer's income.

Materials and Methods

Research area: Due to a favourable climate and fertile land, West Java is one of the important Indonesian provinces for agriculture. With the largest rice producers in Indonesia, this province produces of fruit/vegetable production as well as tea, rubber, palm oil, sugar cane, cocoa and coffee. In this province, 11.98% of the total GDP is from the agriculture sector with 3.7 million people of the total population working in it [1].

The study was conducted in Sukabumi and West Bandung regency of West Java Province (Fig. 1). These two regencies are the most important regencies, which produce a large amount of horticultural products (chili, tomato and lettuce) for local or national, and even for the international market.

The Sukabumi regency is geographically located between 6°57'-7°25' South latitude and 160°49'-107°00' East longitude, and has an area of 416,100 ha, which is 11.21% of the West Java province or 3.01% of the of Java Island. The average rainfall is 144 mm to 2805 mm and the average temperature is 20 to 30°C with a relative humidity in the range of 85-91%. The total population of Sukabum regency is 2.3 million, with a 1.22% population growth rate and 572.84 people/km^2 population density [29]. There are about 0.9 million economically active people with 33.65% of them work in agriculture, followed by industrial sector 17.77%, trade sector 19.29%, service sector 9.96% and others 19.23%. Irrigation for 65,855 ha of paddy fields is based on irrigation systems that were built by the local government (19,029 ha) and on rainfall (20,554 ha), whereas the rest use other irrigation methods such as irrigation network built by farmers, provincial government and central government. Dry land in Sukabumi regency is mostly used for yards/villages (23,046 ha); followed by dry farm (70,958 ha); 68,460 ha for estate; and 73,728 ha of state forest [29].

The West Bandung regency has 130,577 ha area spread over 60°41' to 70°19' South latitude and 107°22' to 108°05' East longitude, with an average altitude of 110 m and the maximum 2,242.9 m above mean sea level. The average annual rainfall is 1500-4000 mm with an average temperature of 19-24°C [30]. Out of the 1.51 million total population of this regency reagent, there are about 0.58 million economically active people; the maximum number of those (25.95%) subscribe to agriculture and farm work as their livelihood, followed by industrial sector 18.79%, trade sector 17.35%, service sector 15.17% and others 22.75%. Moreover, agriculture occupies the largest land use (66,500 ha) followed by 50,151 ha for protected area; 12,159 ha for non agriculture; and 1,769 ha for others.

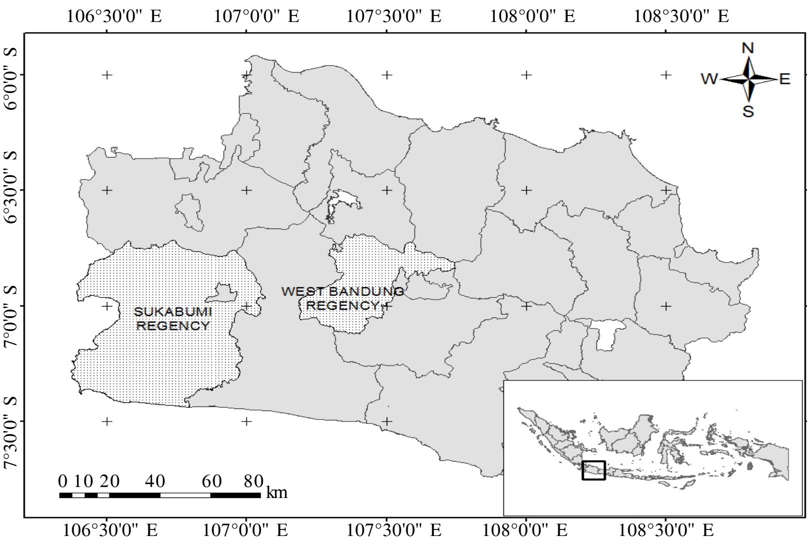

Figure 1. Location of Sukabumi and Bandung regency in West Java province.

Data collection and analysis: Data were collected during 2010 production season. Approximately 580 farm households (230 respondents in Sukabumi regency and 350 in the West Bandung regency) were interviewed using a structured questionnaire. The research was conducted in the medium and highland areas of the Sukabumi regency, and only in the highland area of West Bandung regency. Altitude of medium land is considered between 300- 800 m, and more than 800 m above sea level considered as highland [31]. Based on the main vegetable production, the survey focused on chili production for the Sukabumi regency. Meanwhile, for the West Bandung regency, it focused on tomato and lettuce production.

Information was collected on the environment, technology used, supply chain management, and socio-economic factors that influence protected cultivation (greenhouse technology) of horticultural crop in West Java Province. The research was based on both primary and secondary data collected. Primary data was collected through the questionnaire survey, observation, reconnaissance survey, key informants, group discussion and interviews. The secondary data were collected from the Department of Agriculture of Indonesia, Indonesian Centre of Research and Development of horticultural crop, and other related offices. Documents from farmers' organisations, extension workers, and published statistics were also collected. Farm households typologies in both areas were analysed by using two multivariate statistical techniques, PCA and CA. Principal component analysis (PCA), used to reduce the number of variables into a new set of components that has a linear combination of the original set. The new set of this component was used as an input to cluster analysis (CA), the second step, for identifying the typology of farm households.

By using PCA, all the original interdependent variables were reduced into a set of independent variables that is much easier to understand and can be used in cluster analysis [32, 33]. First, data set was checked for its appropriateness for this analysis. Data were not considered appropriate for PCA if it is largely independent or correlates very strongly. Kaiser-Maier-Olkin test (KMO) and Bartlett's sphericity test were used [34, 35]. Selected variables were used to construct the factor using PCA. The factors were rotated using the varimax method (orthogonal rotation). By using this method, all variables having highly correlated variables were selected to factor, which maximally correlated with only one principal component and a near zero association with the other components. Based on the Kaiser's criterion [35], all the factors with an eigenvalue of one were kept for further analysis. This criterion is considered valid if the number of variables is less than 30 [35]. It was suitable for this research because 23 variables (Table 1) were used to construct a factor using PCA.

Age of the head of the household might affect the adoption of new technology. Young people may have broad knowledge and open mindset, which has an impact on adopting new technology, while older farmers with longer experience in the agricultural field might be more conservative, therefore they may prefer to continue their work traditionally. Family size may influence when it comes to producing enough food for the whole family, which may or may not give them a free hand to invest in new technology. Education of head household was expressed as two variables: finished 6th grade and above, and non-formal education. Non formal education corresponds to the ability of writing and reading of the head of the household, that is usually was obtained from traditional educational or training institutions.

Table 1. Variables used in PCA analysis.

Name of variable	Description of units
The personal attributes of head of households	
Age	Years
Experience	Years
Family size	Number of family size
Education of household head	
Level of education	1 if finished 6th grade or above; 0 non formal education
Agricultural production	
Area of agricultural farm	ha
Yield	kg/ha
Income	
Return per hectare	Total return per hectare
Environmental factor	
Soil quality	Degree of soil fertility
Water availability	Level of water availability
Supply chain management	
Marketing channel	Distribution channel level
Infrastructure quality	
Road quality	Degree of road quality
Communication services	Communication service level
Transportation	
Availability of transportation mode	Degree of availability of transport
Accessibility to market places	Level of access to market
Access to field	Field access level
Agriculture input access	Stage of agriculture input access
Technology attributes	
Drainage	Adoption level of drainage technology
Pruning	Stage of adoption of pruning technology
Fertilizers	Level of adoption of fertilizer technology
Pest and disease	Degree of adoption of pest and disease technology
Institutional attributes	
Training experience	Degree of training experience
Government support	1 if receiving government support; 0 otherwise

Agricultural production is considered to be one of the most important factors in adoption of new technologies. The large agricultural land may have a greater capacity to adopt new technology. Income is expressed as return of crop per hectare. Cash is required for making initial investment to subscribe to newer technologies.

Environmental factors such as soil quality and water availability may influence the desire/suitability of the farmer/farm to improve their production by applying new technology. Marketing channel in terms of supply chain management might affect on the willingness of the farmer to adopt new technology. The lengthy marketing channel cause delays in payment for farmers and most farmers suffer capital losses [36]. By adopting new technology, it is expected to increase the quality of agricultural production that can bring access to modern marketing channels. Moreover, a farmer might get higher selling price of their product. Availability of infrastructure and accessibility to transportation are mostly requirement for adoption of new technology.

The technology considered in this study was expressed as four variables, i.e., level of drainage adoption, level of pruning, level of applying fertilizer, and level of pest and disease management. The selection of this technology is based on the appropriateness and popularity that most farmers can acquire knowledge support from institutional services.

Cluster analysis (CA) technique was used to determine the number of clusters or groups within farm households. Farm households within a certain group must be similar to each other, yet every group should be different than each other. Since there is no specific procedure to find the most appropriate number of clusters, the hierarchical method and the partitioning method could be used for it [37]. Lattin *et al.* [34] suggested that the k-cluster solution could be found by bringing together two clusters from the k+1 cluster solution, meanwhile the partitioning procedure classifies the farm household into a given number of clusters.

To find the best solution for the cluster, Ward's hierarchical procedure was used to minimize the variation of each cluster and determine the clusters, which have equal size [26, 38]. The hierarchical tree (dendrogram) as the Ward's method, gives the optimal number of clusters. A dendrogram is a graphical representation of the hierarchy of nested cluster solutions. The solution was achieved by plotting the number of clusters based on the variation between the distance coefficient at one clustering stage and the previous one [38]. The best solution clusters from Ward's method were continued to analyse by using the partitioning clustering method, i.e. the k-means for the most realistic and meaningful for the final solution. Field [35] mentioned that one-way analysis of variance test (Levene's test) can be used to identify the difference in variance between clusters in addition to cluster analysis.

Results and Discussion

Principal component analysis (PCA): To examine from all the data sets of 580 farm households and 22 variables, which could be factored, KMO and Bartlett sphericity tests were applied. The results showed that all of KMO indicators were greater than 0.5, while Bartlett sphericity test was highly significant (p<0.001). This confirmed that all the variables are related and could be continued to construct factor by using PCA.

PCA for Sukabumi Regency - medium land: In total, 22 variables were included in the PCA where it was found that five principle components were with eigenvalues greater than 1 that were used for further analysis for medium land in Sukabumi regency. The results of PCA for medium land in Sukabumi regency are shown in Table 2.

Results revealed that the first component (F1), which explained 18% of variance, is strongly correlated with the agricultural production, and three technology attributes such as drainage, fertilizer uses and pest and disease management. The second (F2) and third (F3) components explained 15% and 13% of variance, respectively. These components are mostly related to infrastructure, availability and accessibility of transportation in medium land Sukabumi regency. Those factors, as expected, play an important role for farmers to adopt new technology that can improve the quality and quantity of their product. Besides this, lack of infrastructure and accessibility of transportation are obviously considered as the constraints to adoption of technology to farmers.

Both the fourth (F4) and the fifth components (F5) explained 11% of total variance. F4 is positively related to institutional attributes that support farmers in adopting new technology, such as training experience and government support; but it is negatively associated with water availability as one of the environmental factors. The last component (F5) comprises age, experience, education of the household's head and soil quality in medium land Sukabumi regency. Age and experience are positively linked, which indicates that the older and experienced farmer tend to adopt new technology faster than younger ones. All these variables explained 68% of total variability.

Table 2. Factor of loading on the adoption of new technology in medium land of Sukabumi Regency.

Name of variables	Component				
	F1	F2	F3	F4	F5
Personal attributes of head of households					
Age	-0.029	0.13	-0.064	-0.133	**0.838**
Experience	-0.013	0.075	-0.155	-0.108	**0.726**
Family size	0.035	-0.146	-0.605	0.288	-0.095
Education of head of house hold					
Level of education	0.271	0.077	-0.194	-0.057	**-0.56**
Agricultural production					
Area of agricultural farm (ha)	**0.897**	-0.104	0.056	-0.137	-0.052
Yield (kg/ ha)	**0.904**	-0.106	0.071	-0.14	-0.05
Income					
Return per hectare	**0.82**	-0.195	0.095	-0.086	-0.006
Environmental factor					
Soil quality	-0.245	0.063	0.149	0.49	**0.536**
Water availability	-0.001	-0.009	0.056	**-0.602**	-0.097
Supply chain management					
Marketing channel	-0.064	-0.447	0.185	-0.482	0.244
Infrastructure quality					
Road Quality	0.264	**0.611**	0.236	-0.331	-0.372
Communication services	-0.174	**0.681**	0.257	-0.016	-0.036
Transportation					
Availability of transportation mode	0.007	0.042	**0.86**	0.066	-0.157
Accessibility to market places	0.028	**0.648**	0.512	0.237	0.119
Accessibility to field	0.084	0.309	**0.882**	0.074	0.005
Agriculture input access	-0.156	**0.774**	0.249	-0.013	0.235
Technology attributes					
Drainage	**0.676**	0.399	-0.213	0.284	-0.178
Pruning	0.033	**0.779**	-0.014	-0.04	0.125
Fertilizers	**-0.726**	-0.014	0.045	-0.424	0.295
Pest and disease	**0.692**	0.37	-0.081	0.39	-0.19
Institutional attribute					
Training experience	0.101	0.007	0.316	**0.697**	-0.196
Government support	-0.029	-0.293	-0.387	**0.572**	-0.109
Eigen value	4.04	3.26	2.78	2.40	2.37
Variance (%)	18	15	13	11	11
Cumulative variance (%)	18	33	46	57	68

Note: Loading values less than 0.5 are ignored.

PCA for Sukabumi Regency - highland: The clustering of 22 loading variables into 6 factor components explained the adoption of new technology among farmers in highland Sukabumi (Table 3). It is shown that the first component explains 15% of variance, the second one explains 12%, the third is 12%, the fourth is 10%, the fifth is 8% and the sixth is 7% of total variance, then together the six factors explained 64% of the cumulative variability. The first component (F1) included the agricultural production, comprising area of agriculture, yield (kg/ha) and income of farmers as major variables. These variables explained 15% of total variability. Increasing income and productivity that can be gained from new technology may lead farmers to adopt it easily.

Both the second (F2) and the third component explained 12% of total variability, which are positively associated mainly with infrastructure and transportation. F2 mainly comprises road quality, availability of transportation and accessibility to market places. The rate of adopting new technology depends on the good quality of roads, and convenience of farmers to deliver their product to the market. Meanwhile, the third component (F3) comprises communication and accessibility to the field. This means that the communication connectivity of farmers to exchange information and road connectivity to trade are important factors for farmer to adopt new technology.

Ten percent of variance was supported by the fourth component (F4), which comprised personal attributes of the head of the household. It revealed a positive association with age, family size and experience. This is confirmed that older farmer who had more experience on farm operations and combined with large family tend to adopt new technology. Increasing the number of family member means larger quantity of food has to be produced, which encourages the farmer towards adoption of new technology.

The fifth component (F5) explained 8% of total variance, which is positively related to technology attribute such as drainage system, pruning and pest disease management. It indicated that in highland areas, these three factors are the most important requirements for adopting new technology.

The last component (F6) explained 7% of variance, which is negatively associated with the level of education of farmers but positively associated with farmers' training experiences. It is revealed that even the level of education is low but the adoption may occur if farmer had more farm operational skills, and knowledge from non-formal training programmes.

PCA for West Bandung Regency - highland: In highland West Bandung regency, the variables were extracted into seven components. These seven components explained 70% of total variability (Table 4). The first component (F1), which explained 13% of variances, is positively correlated with the drainage system, pruning, fertilizing and pest and disease management. Overall, it related to technology that farmers mostly needed in the West Bandung regency.

The second (F2), third (F3) and fourth (F4) components are almost as important as the first component, each explained 12% of variance. The second component is positively related with agricultural production. This implies that adopting new technology has to consider the area of agriculture (ha), yield (kg/ha) and income

Table 3. Factor of loading on the adoption new technology in highland of Sukabumi regency.

Name of variable	Component					
	F1	F2	F3	F4	F5	F6
Personal attributes of head of households						
Age	-0.014	0.007	0.148	**0.88**	0.023	0.002
Family size	-0.132	-0.289	-0.109	**0.533**	0.091	0.116
Experience	0.103	0.149	0.038	**0.837**	-0.073	-0.072
Education of head of house hold						
Level of education	0.132	-0.006	0.207	0.01	-0.212	**-0.533**
Agricultural production						
Area of agricultural farm (ha)	**0.979**	0.059	0.104	-0.007	0.008	0.033
Yield (kg/ ha)	**0.989**	0.063	0.061	-0.006	0.01	0.021
Income						
Return per hectare	**0.985**	0.068	0.024	-0.007	0.014	0.012
Supply chain management						
Marketing channel	-0.025	-0.191	**0.7**	0.061	0.072	-0.105
Infrastructure quality						
Road quality	0.113	**0.776**	0.25	-0.134	-0.077	0.134
Communication services	0.068	0.455	**0.565**	0.084	-0.073	0.379
Transportation						
Availability of transportation mode	0.006	**0.788**	-0.255	0.164	0.104	-0.134
Accessibility to market places	0.076	**0.749**	0.028	-0.06	-0.11	0.293
Accessibility to field	0.126	0.092	**0.73**	0.053	-0.144	0.396
Agriculture input access	-0.045	0.137	0.157	0.236	-0.008	0.42
Technology attributes						
Drainage	-0.074	-0.043	-0.17	-0.073	**0.657**	0.103
Pruning	0.014	-0.116	0.075	0.036	**0.705**	-0.06
Fertilizers	-0.21	0.024	-0.462	0.075	-0.279	0.049
Pest and disease	0.129	0.157	0.369	0.114	**0.646**	0.09
Institutional attribute						
Training experience	0.179	0.05	0.04	-0.114	-0.036	**0.674**
Government support	0.043	-0.405	-0.586	-0.083	0.003	0.194
Eigen value	3.09	2.38	2.32	1.92	1.54	1.43
Variance (%)	15	12	12	10	8	7
Cumulative variance (%)	15	27	39	49	57	64

Note: Loading values less than 0.5 are ignored.

Table 4. Factor of loading on the adoption new technology in highland of West Bandung Regency.

Name of variable	Component						
	F1	F2	F3	F4	F5	F6	F7
Personal attributes of head of households							
Age	0.073	0.021	0.039	0.185	**0.886**	-0.054	-0.014
Family size	0.089	-0.091	-0.074	-0.026	0.258	0.162	**-0.679**
Experience	-0.047	0.003	-0.02	-0.098	**0.909**	-0.057	0.032
Education of head of house hold							
Level of education	0.003	0.026	-0.11	-0.182	-0.139	-0.204	-0.434
Agricultural production							
Area of agricultural farm (ha)	0.036	**0.915**	-0.154	0.075	0.011	0.045	-0.037
Yield (kg/ ha)	0.02	**0.974**	-0.15	-0.079	0.007	0.06	0.01
Income							
Return per hectare	0.007	**0.869**	-0.04	-0.262	-0.01	0.017	0.065
Environmental factor							
Soil quality	0.078	-0.062	-0.049	-0.039	0.108	**0.756**	0.177
Water availability	-0.194	-0.035	-0.176	**-0.555**	0.053	0.283	0.204
Supply chain management							
Marketing channel	0.11	-0.02	**0.588**	0.312	-0.085	-0.168	-0.383
Infrastructure quality							
Road quality	0.052	-0.182	**0.648**	-0.006	-0.036	-0.01	-0.074
Communication services	0.176	-0.076	**0.865**	-0.029	0.087	-0.139	0.167
Transportation							
Availability of transportation mode	0.047	-0.144	0.215	**0.844**	0.106	-0.035	0.094
Accessibility to market places	0.187	-0.062	**0.805**	0.299	0.02	-0.003	0.095
Accessibility to field	-0.042	-0.106	-0.055	**0.864**	0.029	-0.087	0.002
Agriculture input access	-0.046	-0.142	-0.019	0.051	0.191	-0.453	0.205
Technology attributes							
Drainage	**0.892**	0.025	0.068	0.029	-0.024	-0.006	-0.132
Pruning	**0.924**	0.006	0.148	-0.007	0.053	0.017	0.167
Fertilizers	**0.566**	-0.128	0.35	0.452	0.096	-0.322	0.122
Pest and disease	**0.873**	0.068	0.143	0.055	-0.02	0.079	-0.164
Institutional attribute							
Training experience	-0.11	0.071	-0.204	-0.277	-0.104	**0.643**	0.071
Government support	0.015	-0.025	-0.207	-0.375	0.164	0.096	**0.623**
Eigen value	2.89	2.68	2.57	2.54	1.83	1.53	1.45
Variance (%)	13	12	12	12	8	7	7
Cumulative varience (%)	13	25	37	49	57	64	70

Note: Loading values less than 0.5 are ignored.

($/ha) of the farmer. The third component (F3) is strongly correlated with the marketing channel, road quality, communication service and accessibility to the market place. Good infrastructure and communication connectivity support the farmers to expand farmers' trade. The fourth component (F4) is positively related to accessibility of transportation and accessibility to the field but negatively related to water availability. This indicated that farmer who cannot access water tend to reject the new technology even there is convenience in the accessibility to field and availability of transportation.

The fifth component (F5) explained 8% of total variance. This component is positively related to age and experience of the head of the household. The sixth component (F6) is positively associated with soil quality and training experience in adopting new technology. The prospects of adopting new technology are high if the farmer gets more knowledge and skill from the training program while having good soil quality. The seventh component (F7) is positively associated with government support but negatively associated with family size. This implies that even with small family, if the effective promotion and extension programme (include training programme for new farming technique, pest and disease management, marketing, etc.) are provided by government agencies, the new technology may be adopted.

The cluster analysis (CA): The components from PCA were analysed using Ward's techniques [26, 39, 40]. By using the dendrogram, the sequence in which farm households were merged into the cluster, including several cutting lines, can be found. A main point in this step is where to "cut" the tree in order to arrive at an appropriate number of clusters which best fit the data set. Dendrogram with 3 possible cutting lines of medium land Sukabumi regency are shown in Fig. 2.

From Fig. 2, it can be seen that shifting the cutting line to the right (from A to C) reduces the number of clusters to two. Line A and B create four and three clusters, respectively. Meanwhile, line C creates only two clusters. The number of clusters should be realistic with respect to the situation observed in the field in order to be accepted as a meaningful classification. Another method to decide the most acceptable cluster is by using K-mean method. Hence, K-mean found the most realistic and meaningful final solution followed by one way analysis of the variance test (Levene's test). This was used to identify the difference in variance between clusters in addition to the cluster analysis. By using K-mean technique, the best solution for classification cluster of medium land Sukabumi regency is three clusters, which show the lowest p-values for one-way analysis of variance for each variable. Lower p-value represented more significant different of a variable among groups. The same method of cluster analysis was also applied for other selected areas.

CA for Sukabumi Regency - medium land: Based on the K-mean result, it is shown that the best solution for cluster in medium Sukabumi regency is three clusters. The characteristics of the selected cluster of farm household and P value of one-way ANOVA for medium land Sukabumi regency are shown in Table 5. Level of education, area of agriculture, yield, income/return per ha, soil quality, water availability, marketing channel, and road quality are significant in differentiating the clusters in medium land Sukabumi regency. All these variables are the variables to construct the adoption-based typology.

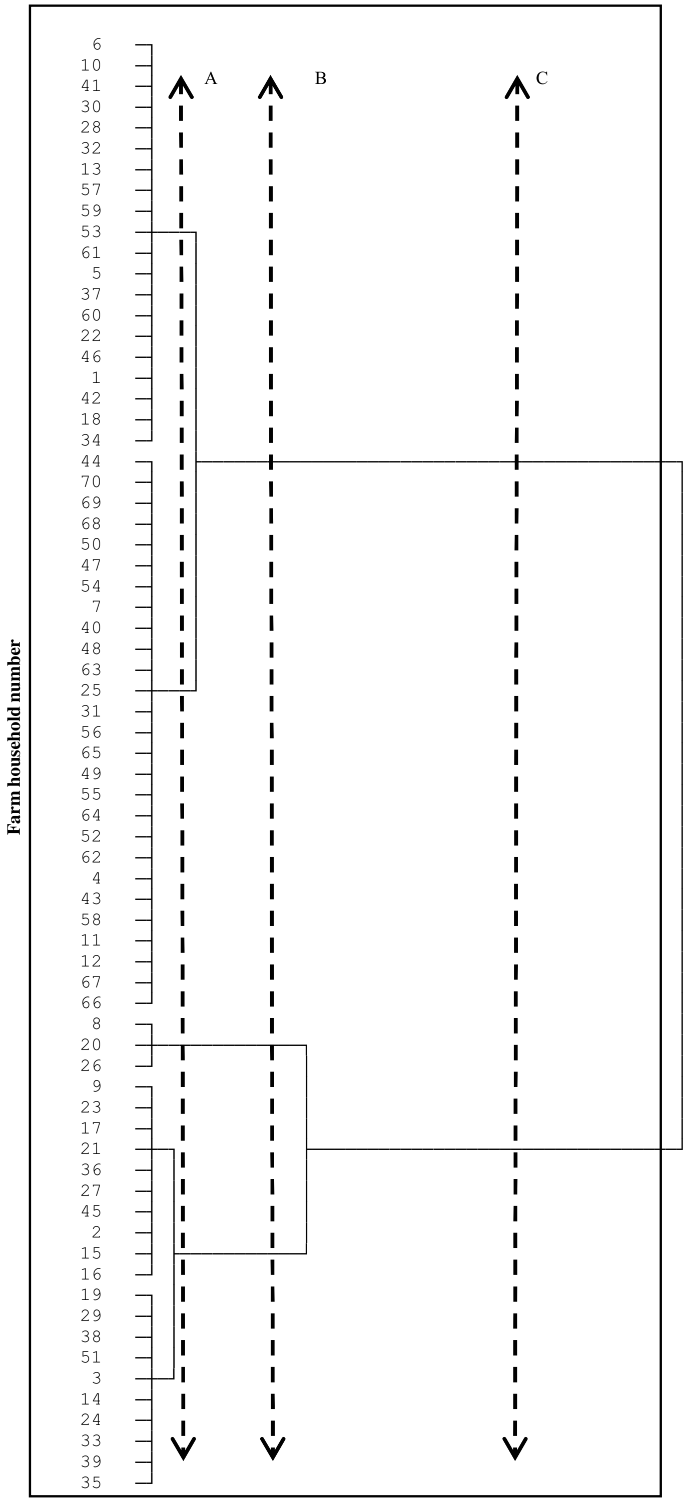

Figure 2. Dendrogram with three possible cutting lines for medium land Sukabumi regency.

Cluster 1 accounts for 60% of farm households. In this cluster, mainly the farm size is larger with higher yield and return per ha as compared to other clusters. The majority of the head of the households have a high level of education and training experience on farming technique. Good infrastructure also played important role in improving their skill and knowledge even there is limited support from government agency. Furthermore, it is found that above average technology was used except for the fertilizer. Cluster 2, which accounts for 36% of farm households, comprised mainly

Table 5. Characteristics of selected cluster and test statistics of one-way ANOVA for medium land Sukabumi regency.

	Cluster 1 N= 42	Cluster 2 N = 25	Cluster 3 N = 3	Cluster mean	Cluster S.D	P-value
Personal attributes of head of households						
Age	43.69	47.4	43.33	45.00	8.46	0.211
Family size	3.17	3.04	4.67	3.19	0.79	0.002
Experience	15.29	19.2	18.33	16.81	7.64	0.119
Education of head of house hold						
Level of education	1	0.8	1	0.93	0.26	0.007
Agricultural production						
Area of agricultural farm (ha)	0.36	0.14	0.25	0.28	0.21	0.000
Yield (kg/ ha)	3,249.19	1,235.32	2,144.67	2,482.61	1,930.64	0.000
Income						
Return per ha ($/ha)	164.87	66.43	96.04	126.77	103.14	0.000
Environmental factor						
Soil quality	0.79	0.83	1	0.81	0.12	0.004
Water availability	1	1	0.67	0.99	0.09	0.000
Supply chain management						
Marketing channel	0.6	0.96	0	0.70	0.46	0.000
Infrastructure quality						
Road quality	0.85	0.68	0.5	0.77	0.19	0.000
Communication services	0.94	0.95	1	0.95	0.12	0.701
Transportation						
Availability of transportation mode	0.88	0.86	0.75	0.87	0.16	0.368
Accessibility to market places	0.87	0.79	0.92	0.85	0.19	0.159
Accessibility to field	0.88	0.83	0.75	0.86	0.14	0.161
Agriculture input access	0.97	0.97	1	0.97	0.08	0.824
Technology attributes						
Drainage	0.99	0.82	1	0.94	0.09	0.000
Pruning	1	0.98	1	0.99	0.04	0.06
Fertilizers	0.8	0.97	0.8	0.86	0.09	0.000
Pest and disease	1	0.82	1	0.93	0.10	0.000
Institutional attribute						
Training experience	3.17	2.44	4	2.94	0.99	0.002
Government support	0.17	0.16	1	0.20	0.40	0.001

of households headed by a less educated person. Furthermore, this cluster has the smallest farm size with an average 0.14 ha, low yield and income compared to other clusters. Lower levels of technology used except technology of fertilizer used could lead to less training experience of the head of the household.

For cluster 3, which comprises only 4% of the total farm households, is characterised based on education level of households' head, agricultural production, technology and institutional attribute. Farm household in this cluster is headed by farmer who has a high level education. Even though farm size, yield and income are relatively below the mean across the cluster, but technologies (except fertilizer) have been adopted at the rate of adoption above the mean across clusters because they had highest level of training experience and the effective training programme, agricultural input and loan provided by government.

CA for Sukabumi Regency - highland: Typology of farm household in highland Sukabumi regency is shown in Table 6.

Cluster 1, which accounts for 8% of farm households, is headed by the household who has adequate experience on agricultural production and has largest agricultural farm size (average farm size of 2.27 ha). Good infrastructure such as roads, communication services, easy access to market, high level of accessibility to the field and agricultural input make this cluster increase their productivity and income. Furthermore, their training experience is above the mean across the clusters even though most heads of this cluster are not young. The farmers receive more information and knowledge from training programmes especially in pest and disease management from various service support. Government institutions rarely supported them. Mostly they got training, information and support from the private sector because this cluster is headed by richer farmers compared to other clusters. This indicates that this cluster can adopt easily new technology with high investment cost.

Cluster 2 comprises 40% of farm households. The cluster has the smallest farm size (average 0.29 ha) and headed by relatively young men. Low in yield and income of this cluster does not make the farmer reject a new technology. Ease in accessibility to the agricultural input is the main reason for farmers not to avoid new technology. Mostly farmers in this cluster use high amounts of fertilizer to increase their production compared to other clusters. Since the majority of this cluster has small sized farms and lower income levels, they improve their skill and knowledge and farm experience from various source of learning include training programs, promotion, and extension programmes supported by the government agency.

Cluster 3 accounts for 49% of farm households, is headed by the older men compared to other clusters. Compared to Cluster 2, this cluster has 0.8 times the average farm size, yield and income. Even though infrastructure and accessibility are better than cluster 2, the adoption of technology is below the mean across clusters, except for pest and disease management. Learning process of farmers lead them to improve their farming technique on pest and disease management from many services that are supported by the private sector. The last cluster (cluster 4) comprises only 3% of farm households, is headed by the youngest farmer with less experience in agricultural field compared to other clusters. Moreover, these farm households are characterised by lower

Table 6. Characteristics of selected cluster and test statistics of one-way ANOVA for highland - Sukabumi Regency.

Name of variable	Cluster 1 N = 13	Cluster 2 N = 64	Cluster 3 N = 78	Cluster 4 N = 4	Cluster mean	Cluster S.D	P-value
Personal attributes of head of households							
Age	40.85	37.70	46.27	33.75	42.06	10.37	0.000
Family size	3.23	3.88	3.73	3.75	3.75	0.72	0.031
Experience	13.39	10.59	14.30	8.75	12.59	5.74	0.001
Education of head of house hold							
Level of education	1.00	0.95	0.96	1.00	0.96	0.19	0.85
Agricultural production							
Area of agricultural farm (ha)	2.27	0.29	0.41	0.31	0.51	0.63	0.000
Yield (kg/ ha)	31,923.06	4,154.20	5,363.90	4,374.98	7,023.62	8,824.08	0.000
Income							
Return per ha ($/ha)	11,297.00	1,495.63	1,792.46	1,552.70	2,444.04	3,139.39	0.000
Supply chain management							
Marketing channel	0.69	0.38	0.69	0.50	0.56	0.50	0.001
Infrastructure quality							
Road quality	0.85	0.70	0.85	0.75	0.79	0.17	0.000
Communication services	0.89	0.73	0.93	0.63	0.84	0.15	0.000
Transportation							
Availability of transportation mode	0.87	0.85	0.93	0.81	0.89	0.18	0.034
Accessibility to market places	0.87	0.76	0.93	0.56	0.85	0.20	0.000
Accessibility to field	0.94	0.80	0.94	0.56	0.87	0.14	0.000
Agriculture input access	0.98	0.99	0.99	0.56	0.98	0.09	0.000
Technology attributes							
Drainage	0.95	0.98	0.96	1.00	0.97	0.07	0.123
Pruning	1.00	0.98	0.98	1.00	0.98	0.08	0.769
Fertilizers	0.80	0.87	0.82	0.85	0.84	0.08	0.001
Pest and disease	1.00	0.91	0.99	0.85	0.96	0.11	0.000
Institutional attribute							
Training experience	3.69	2.92	3.28	2.50	3.15	0.82	0.001
Government support	0.39	0.75	0.17	0.50	0.43	0.50	0.000

quality of infrastructure, difficulty in access to the field, market and agricultural input. Lack of communication service and poor infrastructure prevent farm households from participating in training programmes and thereby restrict adopting new technology. The only technology adopted within this cluster is related to fertilizer.

CA for West Bandung Regency - highland: There are two clusters identified in the West Bandung regency (Table 7).

Cluster 1 comprises 21% of farm households. The average of 0.5 ha of farm size and higher income of farmers are the important factors in distinguishing cluster 1 from cluster 2. Even though the technology attributes have been adopted at the rate below the mean across the cluster and the infrastructure and transportation attribute is less than other cluster, yet the government supported this cluster to increase their skill/knowledge and production through pesticide subsidies, fertilizer subsidies, training programme and bank loans.

Cluster 2 includes 79% of farm households, and it is characterised by good quality of infrastructure and transportation attribute, but less area of agricultural farm with an average of 0.19 ha. The returns per hectare in this cluster are one-fifth of return per hectare of cluster 1. However, these farm households have adopted relatively costly technologies such as drainage system, pruning, fertilizing and pest and disease management, at the rate of adoption above the mean across clusters.

Based on the results of the characteristics for each cluster in research area, the specific strategies for improvement of production system that may be more

Table 7. Characteristics of selected cluster and test statistics of one-way ANOVA for highland West Bandung Regency.

Name of variable	Cluster 1 N = 74	Cluster 2 N =276	Cluster mean	Cluster S.D	P-value
Personal attributes of head of households					
Age	41.65	45.18	44.44	11.46	0.018
Family size	3.72	3.65	3.66	0.99	0.602
Experience	14.72	14.90	14.86	7.52	0.853
Education of head of house hold					
Level of education	0.99	0.93	0.94	0.24	0.049
Agricultural production					
Area of agriculture (ha)	0.54	0.19	0.26	0.34	0.000
Yield (kg/ ha)	15360.92	4003.51	6404.78	9154.33	0.000
Income					
Return per ha ($/ha)	1170.70	200.04	405.26	810.47	0.000
Environmental factor					
Soil quality	0.81	0.80	0.81	0.12	0.446
Water availability	0.97	0.87	0.90	0.14	0.000
Supply chain management					
Marketing channel	0.26	0.74	0.64	0.48	0.000
Infrastructure quality					
Road quality	0.60	0.75	0.72	0.12	0.000
Communication services	0.63	0.98	0.91	0.22	0.000
Transportation					
Availability of transportation mode	0.74	0.91	0.88	0.16	0.000
Accessibility to market places	0.61	0.94	0.87	0.22	0.000
Accessibility to field	0.86	0.92	0.91	0.14	0.000
Agriculture input access	0.96	1.00	0.99	0.07	0.000
Technology attributes					
Drainage	0.93	0.98	0.97	0.09	0.000
Pruning	0.94	1.00	0.99	0.07	0.000
Fertilizers	0.75	0.92	0.88	0.13	0.000
Pest and disease	0.93	0.98	0.97	0.09	0.000
Institutional attribute					
Training experience	2.99	2.33	2.47	1.18	0.000
Government support	0.36	0.23	0.26	0.44	0.017

relevant to groups of farms could be suggested as: a) improve in capacity building of farmer by transferring knowledge of suitable and appropriate technology that include cost cutting in production, integrated pest management system and marketing system; b) empowerment of farmer's group; c) involving farmer in research and development based on the existing problems in the agriculture area; d) improvement on regulation and standard of new farming technique; e) strengthening the role of agriculture extension service in specific areas; f) improvement of physical infrastructure; and g) collaboration of government institution and private sector to promote investment in new technology.

Conclusions

Data on 22 variables from 508 farm households were evaluated by PCA and CA in selected areas of research with respect to adopting new technology, using socio-economic factors.

PCA identified 5 factors that account for 68% of the total variability in medium land Sukabumi regency. The result from cluster analysis led to identification of three clusters. The first cluster is characterised by a higher level of education and headed by households with large farm size, higher yield, higher return per ha. They were also extensive users of technology for drainage, pruning and pest disease management. The second type represents households with less educated, smaller farm size and higher level of fertilizer uses. The third type is characterised by a high level education of farm households with higher adopted technology except fertilizers.

In highland Sukabumi regency, 6 factors influenced on adopting new technology, which accounts for 64% of total variability and 4 clusters, were found by using PCA and cluster analysis. The first cluster represents households headed with a large farm size, and higher adopted technology on pruning and pest disease management. The second type represents a relatively young head of households with the smallest farm size and technology adopted on fertilizers. The third type characterised by households with older men, and the adoption of technology is only for pest and disease management. The fourth cluster is headed by the youngest farmer and less experience in the agricultural field. The only technology adopted within this cluster is fertilizer.

PCA identifies 7 factors that account for 70% of the total variability in West Bandung regency. Results from cluster analysis led to identify two clusters. The first cluster is characterised by households with a large agricultural production but low level of adoption technology. The second type represents households with less agricultural area but higher rate of adoption in drainage systems, pruning, fertilizing and pest and disease management.

From this study, it can be concluded that multivariate statistical analysis method such as PCA and CA are suitable tools for identifying solutions for typical farm households based on socio-economics characteristics that underline the adoption of new technology. Furthermore, the study has emphasised the heterogeneity of farm households that can be used to determine the future use of new technology. Determining strategies should be established based on techno-economic studies of different systems including indicators of profitability but also on the level of dependency on external inputs.

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