J. Agrofor. Environ. 6 (2): 49-52, 2012 ISSN 1995-6983

Agricultural area classification of Bhutan using multivariate analysis

Haruo Uchida
Shikoku Research Center, Western Region Agricultural Research Center (WARC), National Agriculture and Food Research Organization (NARO), 1-3-1 Sen-yu, Zentsuji, Kagawa, 765-8508 Japan, E-mail: uchidah@affrc.go.jp

Abstract: This paper summarized many statistical parameters related to agriculture and rural area of Bhutan using the multivariate analysis method. After understanding factors characterizing agriculture, agricultural regions in Bhutan were classified. Firstly, 22 variables from agriculture statistics 2009 of Bhutan on 7 categories of land use, infrastructure, materials input, labor power, food sufficiency, cash income and sale income were selected in each district. These variables were analyzed by the principal component analysis and six main principal components (PCs) are extracted, which can explain 74.6 % of total proportion. Six principal components were comprehended as "upland- and stock-farming" (1st PC), "agricultural investment" (2nd PC), "dependency on vegetables" (3rd PC), "superiority of irrigation" (4th PC), "inferiority of stock-farming" (5th PC) and "superiority of fruits as the coping mechanism" (6th PC). These six component scores in each district were analyzed by cluster analysis method in order to group agricultural areas. As a result, agricultural area of Bhutan were classified in seven groups as follows; (A) Non-irrigation stock-farming area (B) Low input upland-farming (non-vegetable) (C) Non-vegetable irrigation area (D) Vegetable agriculture area (E) Small scale suburban agriculture area (F) Marginal agriculture area, and (G) Developed infrastructure paddy area
Key words: Bhutan**,** principal components, cluster analysis, area classification.

Introduction

Bhutan is an agricultural nation and 60% of the laboring power of the country is occupied by the agricultural sector. On an average, 70% of the total population live in rural areas and engage in agricultural works most of which small-scale local self-sufficient and labor intensive (MoFA. Gov. of Japan 2012).

There is wide variation in local agriculture and management system in the country. Such kind of localities among the regions can be thought as the result how the region has been well adapted to natural conditions and socio-economic changes. The agriculture and rural area of Bhutan is facing to the latest socio-economic world situation and the global natural environment both of which change extremely.

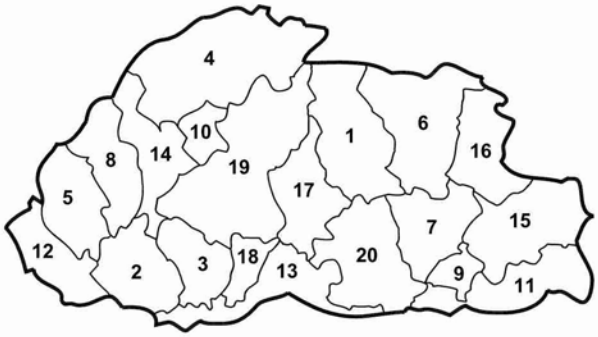

Fig.1. Map of Dzongkhags (districts) in Bhutan

Comprehension of local agricultural diversity in Bhutan, namely, regional classification of agriculture can not only define the relevance of local case studies or case regions in the country but also give the basic idea how the domestic policy and global environment change would impact on Bhutan agriculture. It is because regions (*dzongkhags*, districts) grouped into the same agricultural classification would be thought to react in a same way. In other words, counter-measures to external stimulus could depend on the agricultural classification to which the dzongkhag belonged. Moreover, not only the local natural environment but also the socio-economic conditions' change and its influence brought by the governmental policy, especially five years plan, have contributed to establish the agricultural diversity in Bhutan. In this sense, it is significant to reveal which factors, especially socio-economic conditions, act on the agriculture in the regions.

In this paper the author summarizes many statistical parameters related to agriculture and rural area by the multivariate analysis method. After understanding factors characterizing the Bhutan agriculture and its spatial distribution pattern was classified as agricultural regions in Bhutan (Fig.1).

Materials and Methods

Author selects 22 variables from agriculture statistics 2009 of Bhutan on 7 categories of land use, infrastructure, materials input, labor power, food sufficiency, cash income and sale income in each dzongkhag (Table 1).

Here, the values of rice, grain, oilseeds & beans, vegetable in the land use category means harvested area (acre) and fruit which has no cropped area data is showing production (mt), and cattle & yak is showing the number of heads. As for the category of infrastructure, "within 1 hr from motor-road (%)" indicates that the percent of rural household which takes less than 1 hour walking from nearest motor-road, and, canal (km) shows total length of irrigation schemes、farm road (km) has such title as the farm road inventories as of June 2010.

Concerning the category of materials input, chemicals (kl) is the total of 7 kinds of plant protection chemicals (insecticides, herbicides etc.), fertilizer (t) is the total of 9 kinds of chemical fertilizers (urea, suphala etc.). The category of labor power has only one variable which is the percentage of 15-64 aged members in total household members' living and working on farm and stayed more than 6 months.

The category of the food sufficiency also consist of one variable of food for household consumption (%), namely percentage of food grain produced enough for household consumption. Two categories of cash income and sale income are both the most important coping mechanisms. Three variables of the cash income category shows counting on outside of households and 6 variables of the sale income category means self-help effort within households.

Table 1. Categories and input variables for Principal Component Analysis (PCA)

Category	Input variable	Category	Input variable
Landuse	Paddy (acre)	Labor power	Working age 16–64 population (%)
	Grain (acre)	Food sufficiency	Food for household consumption (%)
	Oil seeds & beans (acre)	Cash income	Borrowed from neighbours (%)
	Vegetable (acre)		Cash remittance (%)
	Fruit (mt)		Off farm activities (%)
	Cattle & yak (head)	Sale income	Potato (%)
Infrastructure	Within 1 hr from motor–road (%)		Vegetables (%)
	Canal (km)		Fruits (%)
	Farm road		Forest products (%)
Materials input	Chemicals (kl)		Dairy and meat products (%)
	Fertlizer (t)		Hire out of bullocks etc. (%)

Each of 22 variables is standardized as to have 0.0 average and 1.0 variance in the country (20 dzongkhags) respectively. Using these standardized 22 variables several principal components are extracted and summarized in accordance with their relevance (see Smith, 2002). Finally cluster analysis is performed to classify 20 dzongkhags into groups according to principal components (see Oksanen, 2012). The similarity between two clusters is defined by the Euclid interval estimated from the characteristic values, namely principal component values, and centre of gravity is used as the characteristic value of the cluster after joining two clusters. In this way, calculations are continued until 20 dzongkhags become one cluster.

Results and Discussion

Principal components of agriculture: Firstly, 22 variables from agriculture statistics 2009 of Bhutan (Gov. of Bhutan 2010) on 7 categories of land use, infrastructure, materials input, labor power, food sufficiency, cash income and sale income are selected in each dzongkhag (Table 1). These variables are analyzed by the principal component analysis. Consequently, six main principal components are extracted, which can explain 74.6 % of total proportion. (Table 2).

Table 2. Factors (PCs) and cumulative proportion

Factor	Eigenvalue	Proportion (%)	Cumulative (%)
1	4.4443	20.2	20.2
2	3.3928	15.4	35.6
3	3.3037	13.8	49.4
4	2.2558	10.3	59.7
5	1.7129	7.8	67.5
6	1.5725	7.2	74.6

Table 3 shows extracted main six principal components (PCs) and its factor loading. First principal component (1st PC, proportion is 20.2%) consists of three variables of land use category, grain, oilseeds & beans and cattle & yak, which can mean “upland and stock-farming”. Thus, each PC is summarized in name by its important variables.

Table 3. Extracted principal components (PC) and factor loading

PC	Variable	Loading	PC	Variable	Loading
1st PC	Grain (acre)	0.4272	4th PC	Canal (km)	0.4046
	Oil seeds & beans (acre)	0.4135		Vegetables (%) (income)	0.3855
	Cattle & yak (head)	0.3359		Fruit (mt)	0.3512
				Paddy (acre)	0.3271
2nd PC	Farm road (km)	0.4123	5th PC	Paddy (acre)	0.3186
	Fertilizer (t)	0.3351		Borrowed from neighbours (%)	0.3065
	Forest products (%) (income)	−0.3502		Food for household consumption (%)	0.3061
				Hire out of bullocks etc. (%) (income)	−0.3277
				Dairy and meat products (%) (income)	−0.3562
3rd PC	Potato (%) (income)	0.4131	6th PC	Fruit (%) (sale income)	0.4703
	Chemical (kl)	0.3385		Food for household consumption (%)	0.3349
	Vegetable (acre)	0.3185		Canal (km)	−0.3067
	Hire out of bullocks (%) (income)	−0.3385		Hire out of bullocks etc. (%) (income)	−0.3241

Second principal component (2nd PC, proportion is 16.2%) is showing “agricultural investment” by government and people. Two variables making up of this PC, farm road (km) and fertilizer (t) shows the high investment and, on the other hand, the value of forest products (%) (income) is showing that the investment is low in the forest area. Third principal component (3rd PC, proportion is 13.8%) is “dependency on vegetables”. Dzongkhags depending on

vegetables highly use much chemical. Fourth principal component (4th PC, proportion is 10.3%) is "superiority of irrigation" not only for paddy but also for vegetables and fruits. Fifth principal component (5th PC, proportion 7.8%) is "inferiority of stock-farming". The component indicates that the stock-farming does not prevail in the paddy cultivated area. The last sixth principal component is "superiority of fruits" as the coping mechanism. Not only large fruit producing dzongkhans but also small producing regions without enough infrastructure has same coping mechanism, which is shown by negative factor loading value of canal.

Distribution of principal components: Fig. 2 shows distribution patterns of score of each principal component in the country respectively. Positive 1st PC (showing upland- and stock-farming) concentrates in the southern part of the country. Upland-farming and stock-farming flourish in the south under low elevation and warm weather condition while negative values of the north show not so. Positive 2nd PC (showing agricultural investment) distributes in the middle latitude area and in the low and high latitude areas negative.

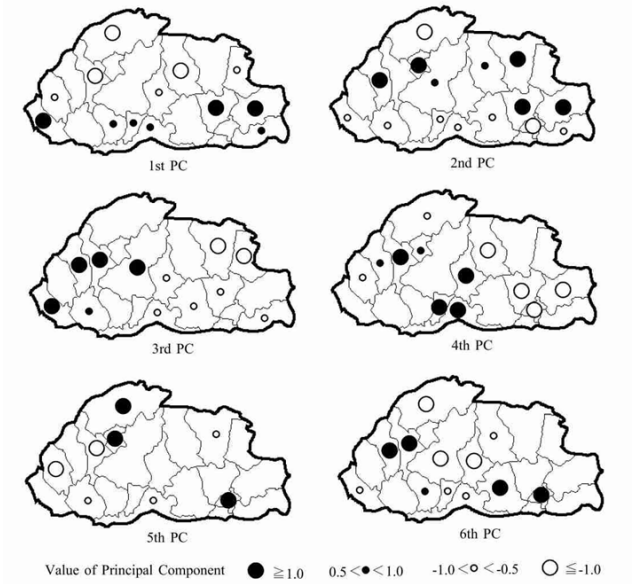

Fig. 2. Score distribution of 6 PCs

Positive 3rd PC (showing dependency on vegetables) distribution indicates that potato is important as coping mechanism and, at the same time, fertilizer is used much in the east regions. Location pattern of 4th PC (showing superiority of irrigation) means irrigated fruits, paddy and vegetable prevail in the middle to west region and, on the other hand, irrigation system is not enough in the eastern regions. Both 5th PC (negative dependency on stock-farming) and 6th PC (showing dependency on fruits as coping mechanism) are not showing clear distribution pattern. It is notable that districts having high production fruits are not necessarily high positive value of 6th PC.

Agricultural area classification:

Six component scores in each district are analyzed by cluster analysis method in order to group agricultural areas. As a result, agricultural areas of Bhutan were classified in seven groups A-G as shown in Fig. 3 in which the number of dzongkhag accords with that of Fig. 1.

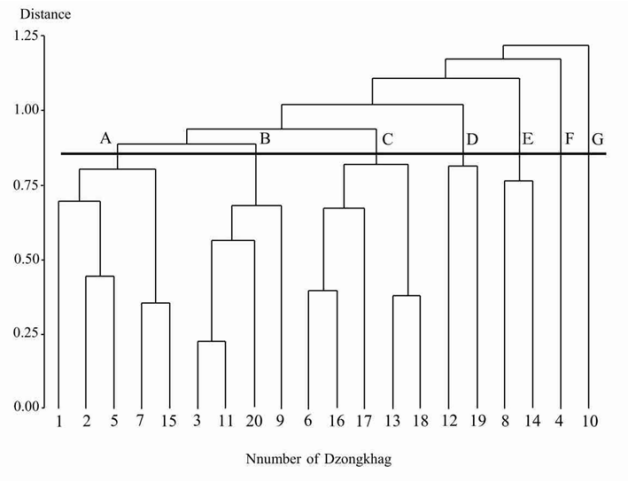

Fig.3. Dendrogram of cluster analysis

Characteristics of each group can be considered by average component score of it (Table 4) as follows:

Table 4. Principal component score of each cluster

Cluster	1st PC	2nd PC	3rd PC	4th PC	5th PC	6th PC
A	0.0531	0.4524	0.0631	−1.0791	−0.6107	−0.1586
B	0.4091	−0.8158	−0.4514	−0.2355	0.4759	1.0789
C	0.0111	0.0741	−0.9821	0.9855	−0.3112	−0.5841
D	0.8494	−0.0921	1.5785	−0.1098	−0.0381	−1.2357
E	−0.9517	0.5204	1.5525	0.8924	−0.6805	1.4103
F	−1.6467	−1.7837	−0.0953	−0.8453	1.3077	−1.3764
G	−0.1058	1.5565	0.2341	0.6888	2.8391	0.4224

Group A: Non-irrigation stock-farming area. 4th PC which indicates the superiority of irrigation is smallest in all groups and 5th PC of negative dependency on stock-farming is also small. 2nd PC is showing agricultural investment is comparatively high. Linking order in Fig. 4 shows districts of no.7 and 15 are far from no.1, 2, 5 by nature. For example, cultivation of vegetables, grains, oilseeds & beans are popular in No.7 and 5 but not in other three districts. Consequently, combination of poor irrigation system and stock-farming can define this group.

Group B: Low input upland-farming (non-vegetable) area. 2nd PC (agricultural investment), 3rd PC (dependency on vegetable) and 4th PC (irrigation) are negative.

According to both of positive value of 1st PC and 5th PC stock-farming can be expected not so flourish. Instead of vegetable cultivation upland-farming of grain, oilseeds & beans is popular in some districts of the group. Since the scale of upland-farming is not enough, farmers sell fruits as coping mechanism.

Group C: Non-vegetable irrigation area. 3rd PC (dependency on vegetable) is the lowest in all groups and 4th PC (superiority of irrigation) is the highest. Irrigation system is developed not for vegetable cultivation but for other crops, may be paddy. Fig. 4 indicates districts of no.13 and 18 are far from no. 6, 16, 17 originally. Cultivation of rice, grain, fruit, oilseeds & beans are popular in the former two districts but not in other three

districts. The combination of developed irrigation system and poor vegetable cultivation can define this group.

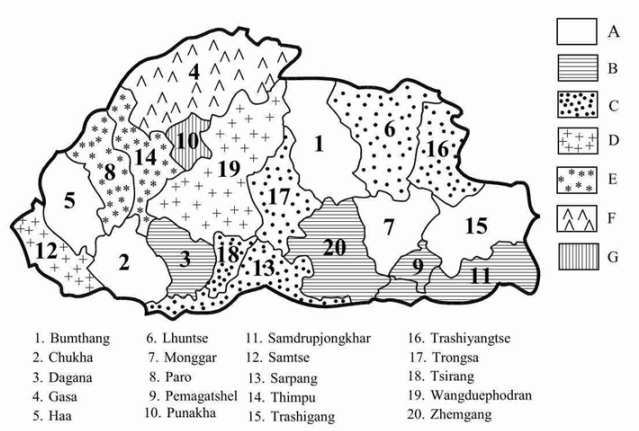

Fig. 4. Agricultural area classification of Bhutan

Group D: Vegetable agriculture area. Highest dependency on vegetable is indicated by the largest 3rd PC in all clusters. There are several differences between these two districts. Cultivated area of grain, oilseeds & beans, fruit area are much larger in no.12 district while total canal length, agricultural investment (chemical and fertilizer) in no.19 district are much larger than in no.12, which original raw data shows. At the same time paddy cultivation, stock-farming and selling potato as coping mechanism are in common.

Group E: Small-scale suburban agriculture area. 3rd PC (dependency on vegetable) is high as well as group D. Although the vegetable cultivated area is very small than that of group D, high values of 2nd PC and 4th PC are showing developed infrastructure and large materials input, which means group E is wealthy. Moreover, 6th PC indicates fruits play a leading role as coping mechanism, which is different from D. Consequently, this group is small-scale suburban agriculture area mainly supported by vegetable and fruit.

Group F: Marginal agriculture area. All principal components deny any agricultural factor. According to the original data "cash remittance (%)" of cash income category and "forest products (%)" of sale income category are high. Livelihood of this group depends on forest product industry and cash remittance from outside.

Group G: Developed infrastructure paddy area. 5th PC (showing negative dependency on stock-farming), 2nd PC (agricultural investment), 4th PC (superiority of irrigation) are high. This group has developed infrastructure, namely farm road, canal and motor-road. Paddy cultivation is more prevalent than other crops and stock-farming as shown by 1st ,3rd and 5th PCs. Additionally, percentage of food grain produced enough for household consumption is second largest in the country, which suggests the group is a livable one.

Conclusion

The author summarized many statistical parameters related to agriculture and rural area by the principal component analysis and cluster analysis methods. Consequently, six principal components were extracted and 7 agricultural clusters could be shown. The regional classification is thought to have been made by not only the local natural conditions but also by socio-economic ones. And we had better to consider the result suggested here could be merely tentative one. Other kind of data can show the different figure. Adding other statistical data such as area of forest and waste land, farming size, income from farming and non-farming etc. could lead us to more comprehensive analysis.

References

Department of Agriculture, Ministry of Agriculture and Forests, Royal government of Bhutan 2010, Agriculture statistics 2009 (Vol.1).

Ministry of Foreign Affairs, Government of Japan, 2012. The latest information on Bhutan and relationship with Japan (in Japanese), (http://www.mofa.go.jp/mofaj/area/bhutan/kankei.html)

Oksanen, J. 2012. Cluster analysis: Tutorial with R (http://cc.oulu.fi/~jarioksa/opetus/metodi/sessio3.pdf

Smith, L. I. 2002. A tutorial on principal components analysis (http://www.sccg.sk/~haladova/principal_components.pdf)

Yamamoto, M., Kikuchi, T., Tsubaki, M. and Sasaki, H. 2001. Agricultural region classification in Thailand and paddy yield. Global environment 6(2): 217-226.