Appendices

Appendix I

AHP process for weighting five indicators of soil fertility

Step 1: Pair wise ranking of indicators (**Judgment matrix**) reached by consensus GYT members

	Yield	Texture	Color	Compactness	Soil depth
Yield	1	4	5	5/2	6
Texture	1/4	1	3/2	5/3	2
Color	1/5	2/3	1	3/2	3
Compactness	2/5	3/5	2/3	1	2
Soil depth	1/6	1/2	1/3	1/2	1

Step 2: Synthesis of judgments matrix step 1 above (Matrix A).

	Yield	Texture	Color	Compactness	Soil depth	**Total**
Yield	1.00	4.00	5.00	2.50	6.00	18.50
Texture	0.25	1.00	1.50	1.67	2.00	6.42
Color	0.20	0.67	1.00	1.50	3.00	6.37
Compactness	0.40	0.60	0.67	1.00	2.00	4.67
Soil depth	0.17	0.50	0.33	0.50	1.00	2.50
Total	**2.02**	**6.77**	**8.50**	**7.17**	**14.00**	**38.45**

Step 3: Calculation of priorities using approximation method (Normalized matrix, each cell is divided by respective column total to obtain the values in the cells e.g. 1/(2.02) = 0.496, in yield column in Step 2 above and as in the highlighted cell below). Average weight (W) is the row value divided by its row total (E.g., 2.453/5.000 = 0.491 for yield).

	Yield	Texture	Color	Compact-ness	Soil depth	**Total**	**Average (W)**
Yield	0.496	0.591	0.588	0.349	0.429	2.453	**0.491**
Texture	0.124	0.148	0.176	0.233	0.143	0.824	**0.165**
Color	0.099	0.099	0.118	0.209	0.214	0.739	**0.148**
Compactness	0.198	0.089	0.078	0.140	0.143	0.648	**0.130**
Soil depth	0.083	0.074	0.039	0.070	0.071	0.337	**0.067**
Total	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**5.000**	**1.000**

Step 4: Consistency measurement (**Consistent matrix**) A*W

Each column value in Step 2 (Matrix A) is multiplied by its respective row W

	Yield	Texture	Color	Compact-ness	Soil depth	**Total**	**Total/w**
Yield	0.491	0.659	0.739	0.324	0.404	2.617	5.334
Texture	0.123	0.165	0.222	0.216	0.135	0.860	5.219
Color	0.098	0.110	0.148	0.194	0.202	0.752	5.090
Compactness	0.196	0.099	0.099	0.130	0.135	0.658	5.078
Soil depth	0.082	0.082	0.049	0.065	0.067	0.346	5.128
					Average Lemda max	**(λ_{max})**	**5.170**

Consistency Index (CI) = (λ_{max}-*n*)/*n*-1,

where,

n = number of criteria's under consideration, here 5 indicators

Consistency Index (CI) = (5.170-5)/ (5-1)

= 0.170

$$Consistency\ Ratio\ (CR) = \frac{CI}{CI_r}$$

where,

CI is Consistency Index and CI_r is random value of CI for r criteria. (in this case five indicators)

$$Consistency\ Ratio\ (CR) = \frac{0.170}{1.11}$$ (Random value of CI for five criteria is 1.11)

$$= 0.038$$

CR is acceptable since it is less than the 0.10 for a 5x5 matrix.

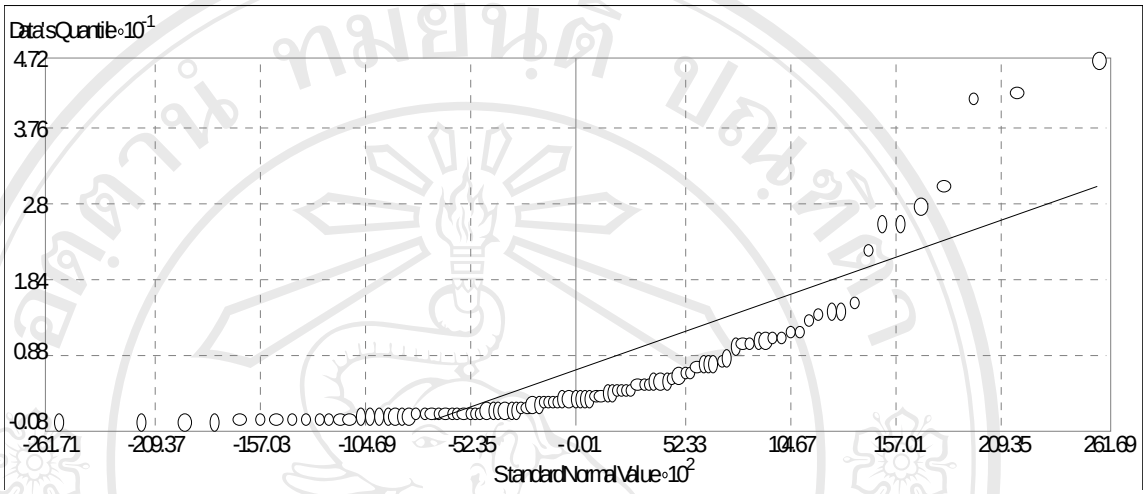
Table. Average consistency index values for different order matrices and acceptable limit of CR

	Size of matrix (*n*)									
	1	2	3	4	5	5	6	7	8	9
Random CI Value	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49
Acceptable CR			<0.05	<0.09	<0.10					

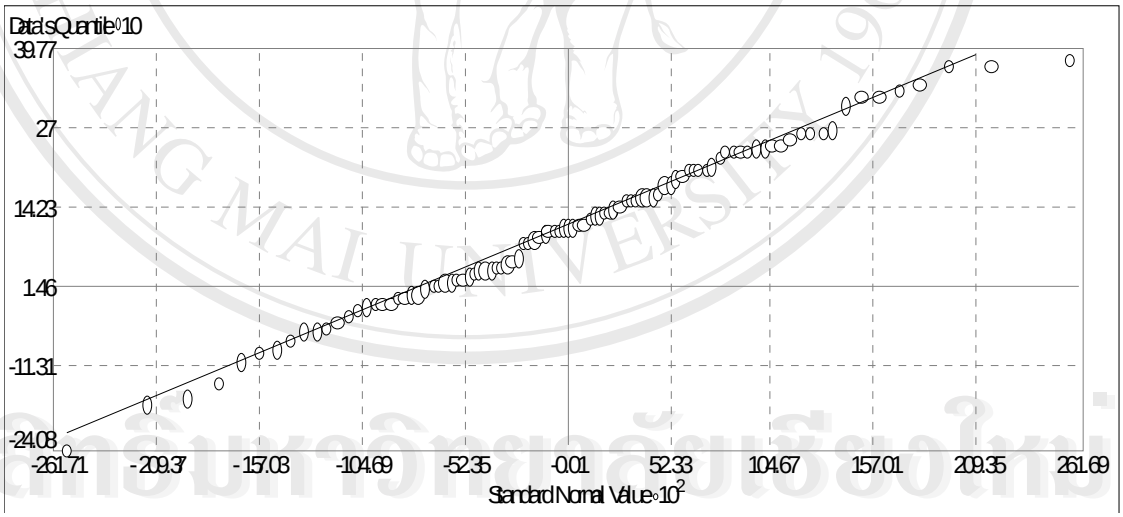
The above steps are based on Saaty (1980) and Alphonce (1997) and further detail on the APH process should consult these references.

Appendix II

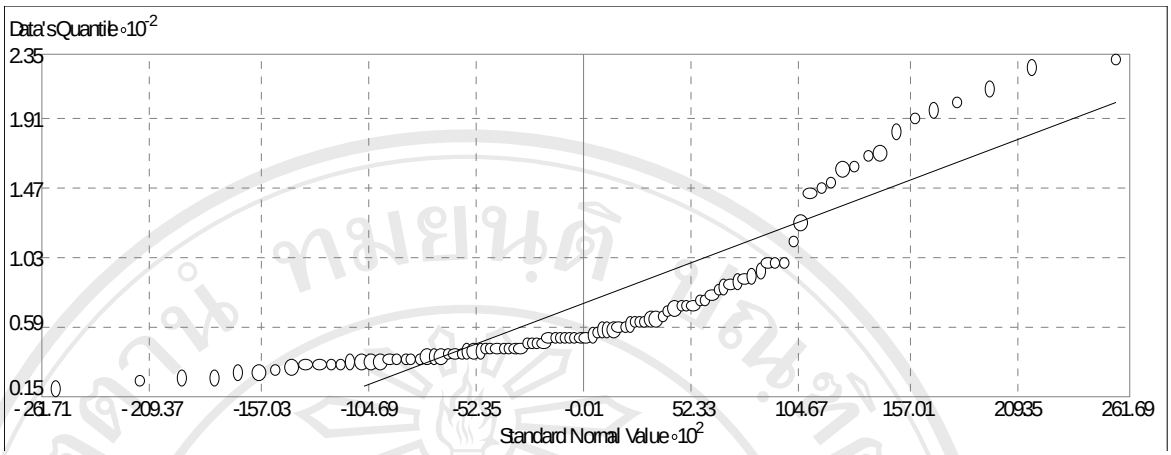
Normality assessment of spatial data using Normal QQ plots



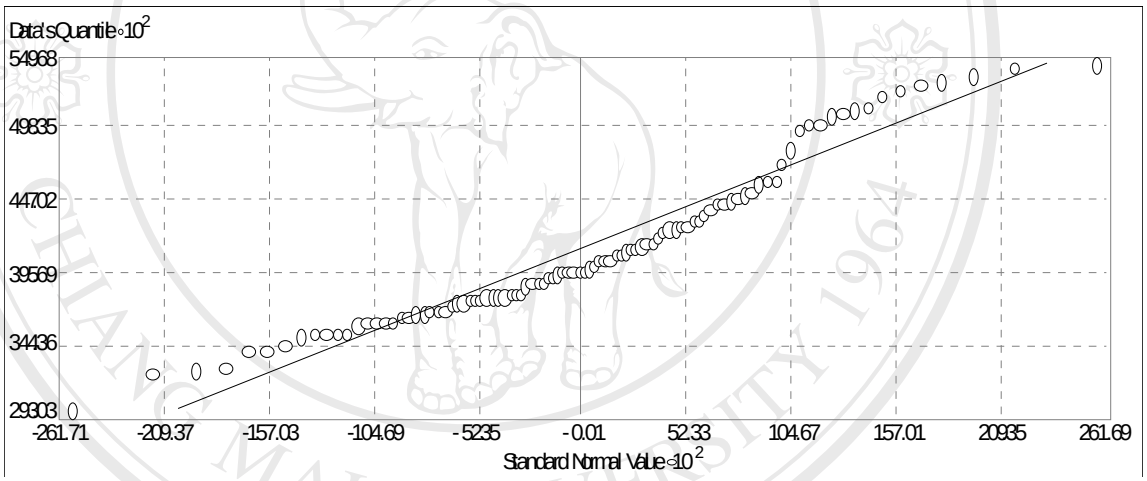
Normal plot 1. Available P data is not normal



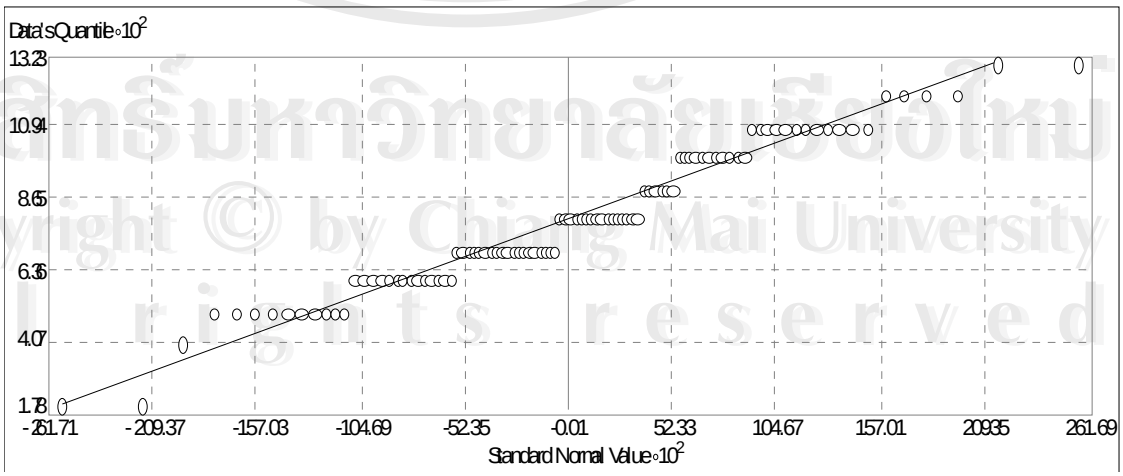
Normal plot 2. Available P data log transformed to normalize



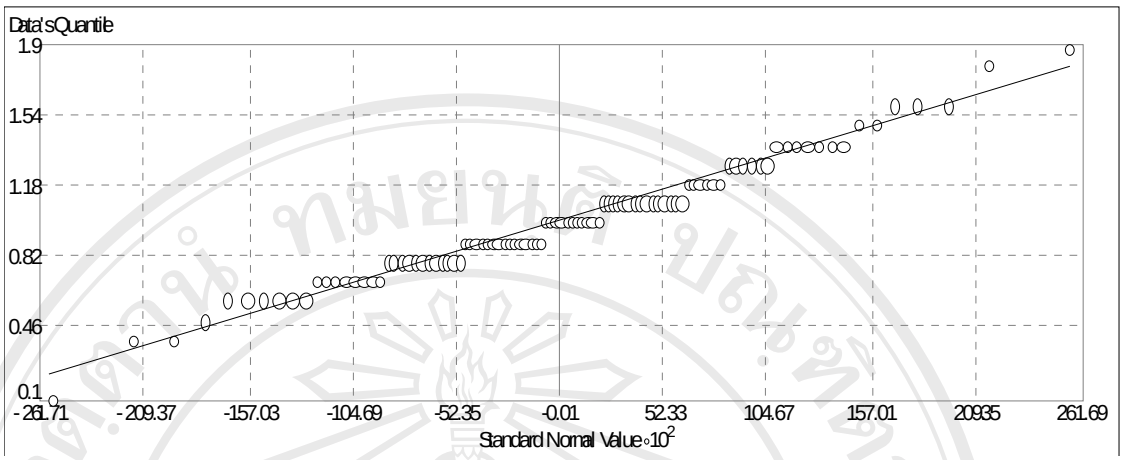
Normal plot 3. Available K data is not normal K



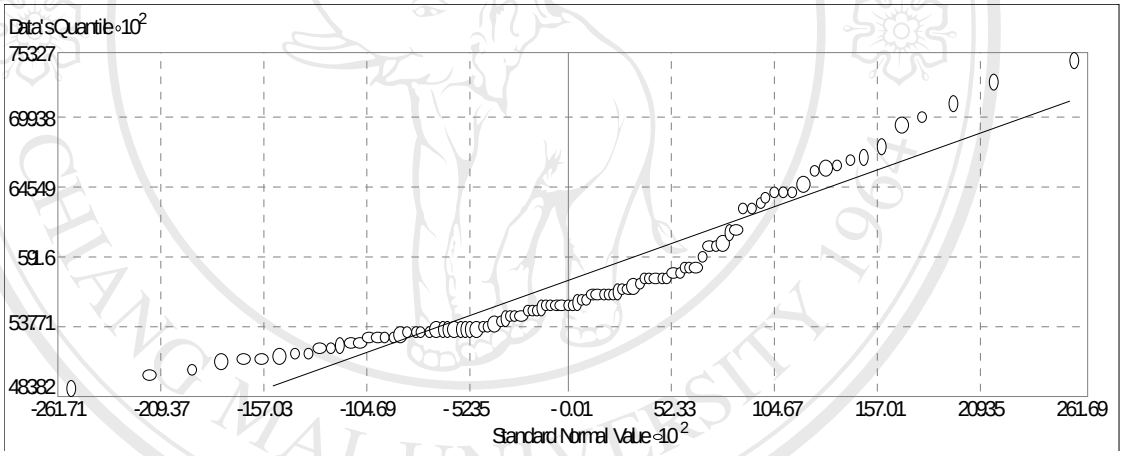
Normal plot 4. Available K data log transformed to normalize



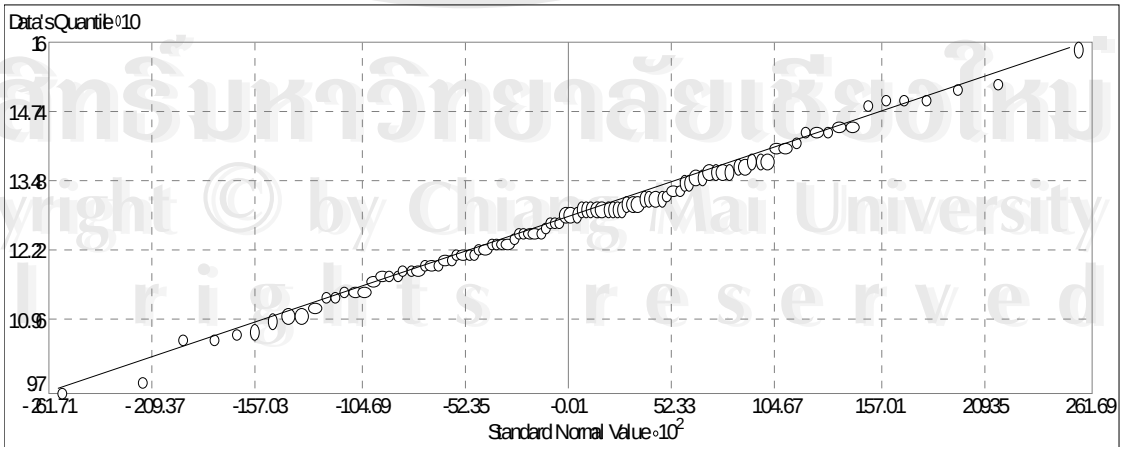
Normal plot 5 .Total N spatial data is normal



Normal plot 6. Organic C spatial data is normal



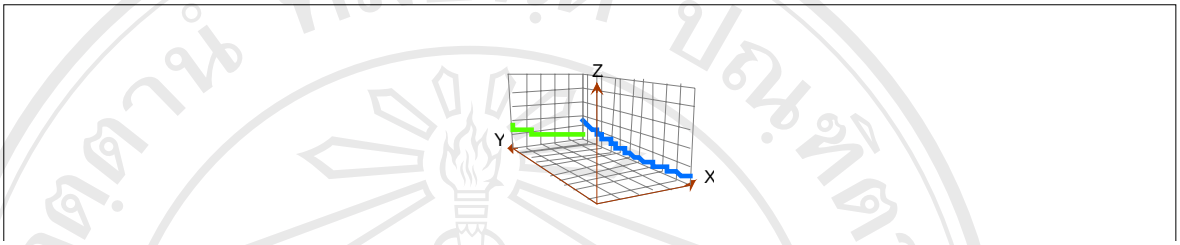
Normal plot 7. pH spatial data is close to normal



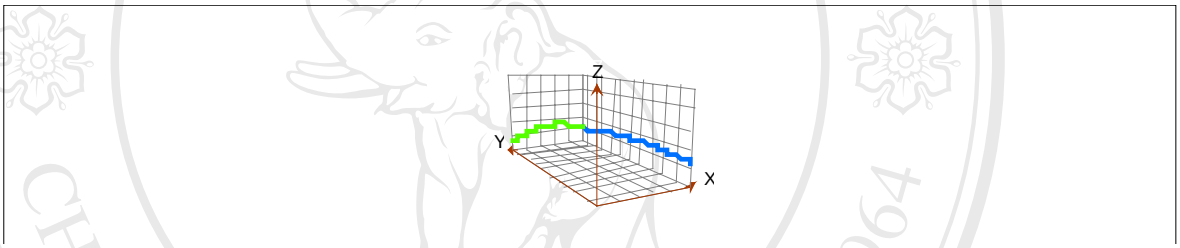
Normal plot 8. Bulk density spatial data is normal

Appendix III

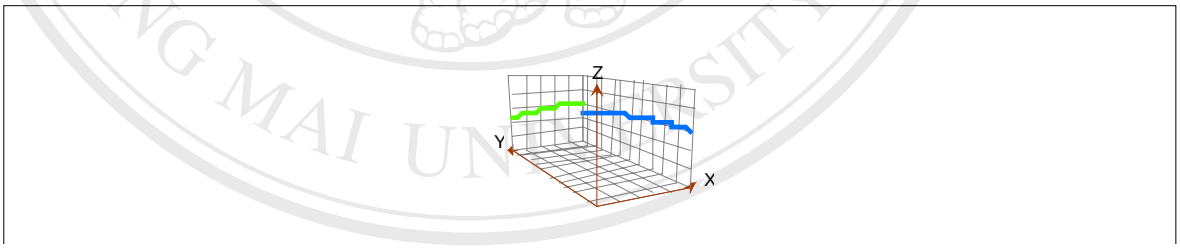
Trend analysis of spatial data



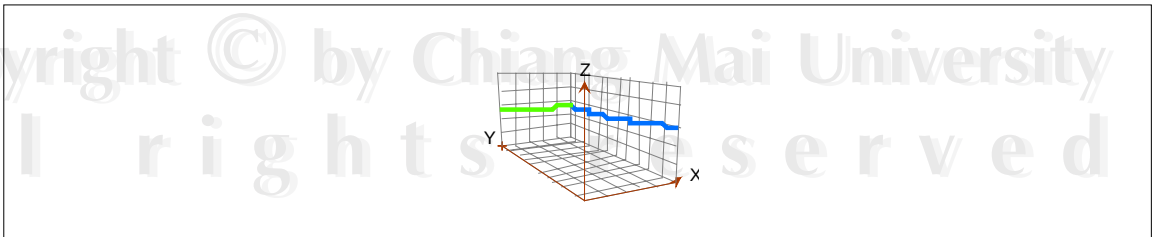
Trend plot 1. Trend of available P, East-West and North-South trends



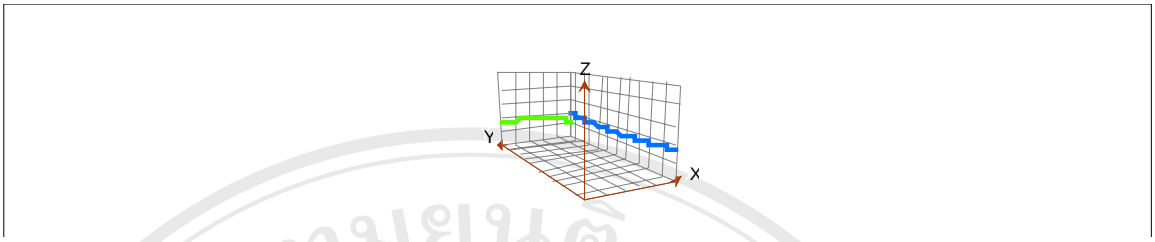
Trend plot 2. Weak or no trend in available K



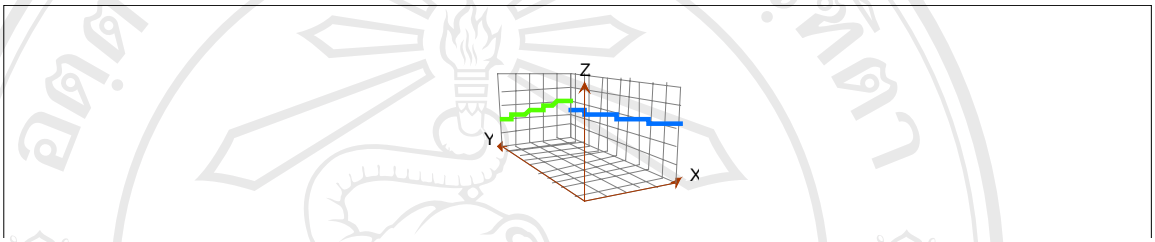
Trend plot 3. Weak or no trend in total N



Trend plot 4. Weak or no trend in organic C



Trend plot 5. Weak or no trend in pH



Trend plot 6. Weak or no trend in bulk density

Appendix IV

Household survey questionnaire format used for soil fertility study

Location: Guma Geog, Punakha district in Bhutan

Sample ID No…….Local Identification…….

1(a). General Information

Name of the informant:……...Age……years. Sex: **M**[ ] **F**[ ]

Village:…… Date:…../…./2005, Interviewer's name:……..

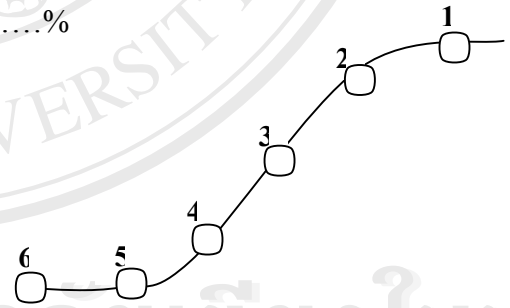
1(b).Geographic/ UTM Co-ordinates soil sampling sites (**UTM zone**: 45)

(Using GPS)
X…….Y……

1(c). Altitude by altimeter:……..masl,

1d. Aspect using compass (Circle one option only)				1. North	2. North-east
3. East	4. South-east	5. South	6. South-west	7. West	8. North-west

1(e). Slope by clinometer: ……..……%



1(f)Circle one slope class option only.		**1**. Top of slope	**2**. Upper slope
3. Mid-slope	**4**. Lower slope	**5**. Bottom of slope	**6**. Not near a slope

2(a). Family information:

Number of persons in household…….

Number of males =……..
Number of females =…….

2(b). Education level of members of households

Number of persons in each education level, write persons in each category.				
Illiterate	Informal	Primary	Secondary	Degree
…….	…….	…….	…….	…….

2(c). Family occupation, number of persons in each category

Farm works =…..	Off-farm works = ….	Students = ….

2(d). Farm labour availability trend in last 5-10 years: Circle one option only

1. Increased	2. Constant	2. Decreased

3(a). Land use

Land use Type	**Land holding**	
	Unit	Quantity.
Wetland		
Dryland		
Pangshing		
Orchard		
Kitchen garden		
Sokshing		
Tsamdrog		
Other(specify)		
Total		

3(b). Land use of sampled field. Circle one option only

1.Wet land	2. Dry land	3.Pangshing/tseri	4.Orchard	5. Kitchen garden
6. Sokshing	6.Tsamdog	7. Other(specify)		

4. Ask how the farmer assesses the soil fertility of this field. Circle one option only

1. Poorly fertile	2. Moderately fertile	3. Highly fertile

5. What are the five most important indicators of your soil fertility?

1.
2.
3.
4
5.

6. Ask the respondent to rank the indicators identified in Question 5 above.

Indicators	Straight ranks (most important =1, second most important = 2, …)

7. Tenancy of this field, circle one option only		
1. Owner managed	2. Shared out	3. Shared in

Soil Fertility Management (SFM) Practices

8. Which of the four fertility management practices does this household used and what is the trend in the HHs use of these practices over the last 5 - 10 years?

SFM practices	**A.** Tick if SFM used	**B.** Change in use over the last 5-10 years, Tick the trend that applies to SFM practice used.		
		1. Increasing	2. Constant	3. Decreasing
e.g FYM/compost	√			√
8.1 FYM/compost				
8.2 Fertilizers				
8.3 Tethering				
8.4 Trash burning				

FYM/compost Management and Use

9. Does the HH make and /or use FYM/ compost (circle one option only)

1. Yes (=1)	Go to next question
2. No (=0)	Go to next section on fertilizer use ad management

10. What types of livestock this HH managing at present? What is the trend of livestock numbers over last 5-10 years?

Livestock type	A. Tick if managed	B. Trend in animal numbers, tick one option per animal type		
		1. Increasing	2. Constant	3. Decreasing
Cattle				
Horses				
Pigs				
Poultry				
g/sheep				
other				

11. What is the trend of livestock bedding materials availability over last 5-10 years? Circle one option only.

1. Increasing	2. Constant	3. Decreasing

12. How has the amount of the different bedding/ litter types available for use by this HH changed over the last 5 - 10 years?

Bedding /litter types	**A.** Tick if type used	**B.** Trend in amount available over the last 5-10 years.		
		1. Increasing	2. Constant	3. Decreasing
1 Pine needles				
2 Broad leaves				
3 Rice/wheat straw				
4 Fodder grass				
5 Others (specify)				

13. Is the amount of **FYM/ Compost** that this HHs has available to each year more, less or equal to the amount needed by the HH? Circle one option only.

1. More than needed	3. About the amount needed	5. Less than needed

14. If it wanted to, could this HH increase the amount of FYM/ Compost it produces? Circle one option only

1. Yes (=1)	**2.** No (= 0)

15. What is the TREND in the total amount of FYM/ Compost that is available to the HH compared to 5-10 years? Circle one option only.

1. Increasing	2. Constant	3. Decreasing

16. If this HH reports that the amount of FYM/ Compost that is available to it has been increasing (a tick in 1 previous question), then what are the reasons for this increase?

Record up to three reasons for this increase	Tick up to 3 reasons mentioned or added	Tick most important only
16.1 We are keeping more animals		
16.2 More animals are being stall fed		
16.3 There is more labor available to collect bedding		
16.4 other (specify)		
16.5 other (specify)		
16.6 other (specify)		

17. If this HH reports that the amount of FYM/ Compost that is available to it has been decreasing (a tick in 3 of question before last), then what are the reasons for decrease?

Record up to three reasons for this decrease.	Tick up to 3 reasons mentioned or added	Tick most important only
17.1 We are keeping less animals		
17.2 Less animals are being stall fed		
17.3 There is less labour available to collect bedding		
17.4 other (specify)		
17.5 other (specify)		
17.6 other (specify)		

Fertilizer use and Management

18. Which fertilizers has this HH heard of?

Fertiliser name	Fertilizer Bhutanese name	Tick only fertilizer type mentioned
Suphala	Maap	
Urea	Kaap	
Single superphosphate	Tshe	
Muriate of potash		
Calcium ammonium nitrate (CAN)		
Never heard of fertilizers	If never heard of fertilizers then go to end of this format	

19. Has any member of this HH ever attended farmer training /demonstration on use of fertilizers? Circle one answer only.

1. Yes (= 1)	2. No (= 0)

20. Has of this HH used fertilizers in this field?

Circle one answer only	1. Yes	Go to the question after next
	2. No	Go to the next question

21. What are the reasons that this HH has not used fertilizers?

Record up to three reasons	Tick up to 3 reasons	Tick the most important reason only
22.1 Fertilizers not easily available		
22.2 Our soil already fertile so we do not need to use		
22.3 We have enough manure so we do not use		
22.4 Do not have enough knowledge/information on how to use fertilizers		
22.5 We like to use fertilizers but cannot afford		
22.6 Other reason (specify)		
22.7 Other reason (specify)		
22.8 Other reason (specify)		

23. When did this HH start using fertilizers?

Record the number of years ago?	……..years ago

24. Why do this HH use fertilizers?

Record up to three reasons.	Tick up to 3 reasons	Tick the most important only
24.1 Because our crop yields were declining		
24.2 Less labor to collect livestock bedding materials		
24.3 Because other farmers were using fertilizers		
24.4 Because other farmers recommended us		
24.5 Because EA recommended us to use it		
24.6 Because fertilizers were given		
24.7 Insufficient FYM due decrease cattle holding		
24.8 Other (specify)		
24.9 Other (specify)		

25. Fertilizers use

Crop	Type of fertilizers					
	Urea (*kaap*)	Suphala (*maap*)	SSP (*tshe*)	CAN	MoP	Other
Rice						
Wheat						
Mustard						
Citrus						
Chilies						
Beans						
Other						
Other						

Curriculum Vitae

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Educational background:

Bachelor of Science (Hons.), Agriculture
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Master of Science, Agriculture (Agricultural Systems)
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Chiang Mai University, Chiang Mai
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Scholarships

European Union; 1995-98

Thailand International Development Cooperation Agency (TICA), Thailand; 2004-06

Working experiences

April 2003 – present	District Agriculture Officer, Agriculture Sector, District Administration, Pemagatshel, Bhutan
May 2002 – May 2003	District Agriculture Officer, Agriculture Sector, District Administration, Punakha, Bhutan
Jan. 1999 – April 2002	Extension Officer, Agriculture Sector, District Administration, Punakha, Bhutan
Oct. – Dec 1998	Trainee Officer, Agriculture Sector, District Administration, Punakha, Bhutan