

**Boron and zinc deficiency in Nepalese soils:
Small-scale variations and the influence of
farming system dependent factors.**

A case study from Sedi Bagar, Kaski District, Nepal.

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**A masters`s thesis in Environmental Geography
Spring 2007**

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Acknowledgements

The process of writing a master's thesis contains bottomless valleys as well as high mountain peaks of mental wellbeing. Still, I look back at the last year's studies as an entirely positive experience. Much of the credit should be given to the fantastic social community at the Institute of Geography, University of Bergen. Here, the fellow feeling is stronger than most places I know.

I am also very grateful to my supervisor, Peter Andersen, who has been supportive and constructive in his feedbacks on this thesis. Peter Andersen is the person that introduced me to the wonderful country of Nepal and the interesting study of farming systems and micronutrients in soils.

The gathering of data could not have done without Roshani Rai. I found her guidance, knowledge and good humour priceless when I was wandering around in a totally unknown country. Dr. Desh Subba at LI-BIRD was also a valuable help during my time in Pokhara.

I have worked hard to produce some good results in this thesis, but in the moment of conclusion, it stands clear for me that the path to the findings is more important than the findings themselves.

Bergen, April 2007

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Abbreviations

| | |
|----------|--|
| AAS: | Atomic Absorption Spectrometry |
| AIC: | Agricultural Inputs Corporation |
| CBS: | Central Bureau of Statistics (Nepal) |
| CEC: | Cation Exchange Capacity |
| DAP: | Diammonium Phosphate |
| DEM: | Digital Elevation Model |
| DTPA: | Diethylene Triamine Pentaacetic Acid |
| FADINAP: | Fertilizer Advisory, Development and Information Network for Asia and the Pacific. |
| FAO: | Food and Agriculture Organization (of the United Nations) |
| FYM: | Farm Yard Manure |
| GIS: | Geographical Information Systems |
| GPS: | Global Positioning System |
| HVC: | High Value Crop |
| IRP: | Independent Random Process |
| LI-BIRD: | Local Initiatives for Biodiversity, Research and Development |
| NARC: | Nepal Agricultural Research Council |
| MoA: | Ministry of Agriculture (of Nepal) |
| MoAc: | Ministry of Agriculture and Co-operatives. |
| NGO: | Non Governmental organization. |

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1. INTRODUCTION.

There is no doubt that agriculture is the most important contributor to the global production of food. This is undeniably also the case for Nepal. In 2002, 93% of the Nepalese workforce was deployed in agriculture (World Bank 2005). It therefore goes without saying that this line of work is vital to most Nepalese families and the national economy as a whole.

Authors such as Sillanpää (1982; 1990) and Carson (1992) suggest that severe nutrient deficiencies are reducing crops on a widespread basis in Nepal, though.

Of the 92 naturally occurring chemical elements, 18 have been proven to be essential elements which plants can not grow and complete their life cycle without (Brady 2004). Among the latter are zinc and boron. These two micronutrients are subject to the main investigations of this thesis and are chosen due to the findings of Mikko Sillanpää (1982; 1990), claiming that the most extensive soil deficiencies in Nepal are those of boron and zinc.

This thesis is not an attempt to falsify or verify Sillanpää's theories, but rather an effort to investigate links between zinc and boron deficiencies and how the farming system is operated in a small village of semi-subsistence agriculture. Researchers state that there are soil deficiencies in the world, but not all of them have theories on why this is the case. To be able to cope with problems, one must have knowledge of the underlying causes.

To obtain such knowledge, a quantitative farming system approach is applied along with a spatial approach. Studying farming system is done to obtain data for further statistical analyses. These data are used to show connections between farming practices and micronutrient levels. The spatial approach is used to add the dimension of space to the analysis, as this is not included in a normal statistical examination.

It is important to remember that this is a case study and therefore not an attempt to make generalizations. It is, however, an attempt to find empiric relationships and in that way contribute to the knowledgebase of farming systems and micronutrient deficiencies in Nepal.

1.1. RESEARCH QUESTION

To what degree are the agricultural soils in the field area zinc and boron deficient and what are the explanatory factors?

The research question covers a lot of different subjects and it should be stated that I will aim my main focus on the farming system dependent factors affecting zinc and boron levels. Factors such as geology, soil cover and pollution will not be given much attention. This is not because they are considered less significant, but rather because of lacking resources and time as well as the limited scope of a master's thesis.

1.2. HYPOTHESES

I have elaborated eleven hypotheses with basis in the research question, which I would like to test and discuss in particular. These were made before and during the field work period and are generally very rigid. This has to some extent been problematic as they have worked as a strait jacket on the research. By this I mean that they have limited the options and the choices I have had. This is obviously also a positive thing, as it has helped me stay on track and maintain focus.

The hypotheses can be classified into five different groups as they address different aspects of the thesis. These are; deficiency issues, farming system, spatial patterns, fertilizers use and fertilizer recommendations / extension service. The hypotheses are graphically displayed in figure 1. A short presentation of each hypothesis is included in this chapter.

It is important to have in mind that this is a case study and the hypotheses are therefore only valid in my study area. In other words, they are not meant to make any predictions about other areas.

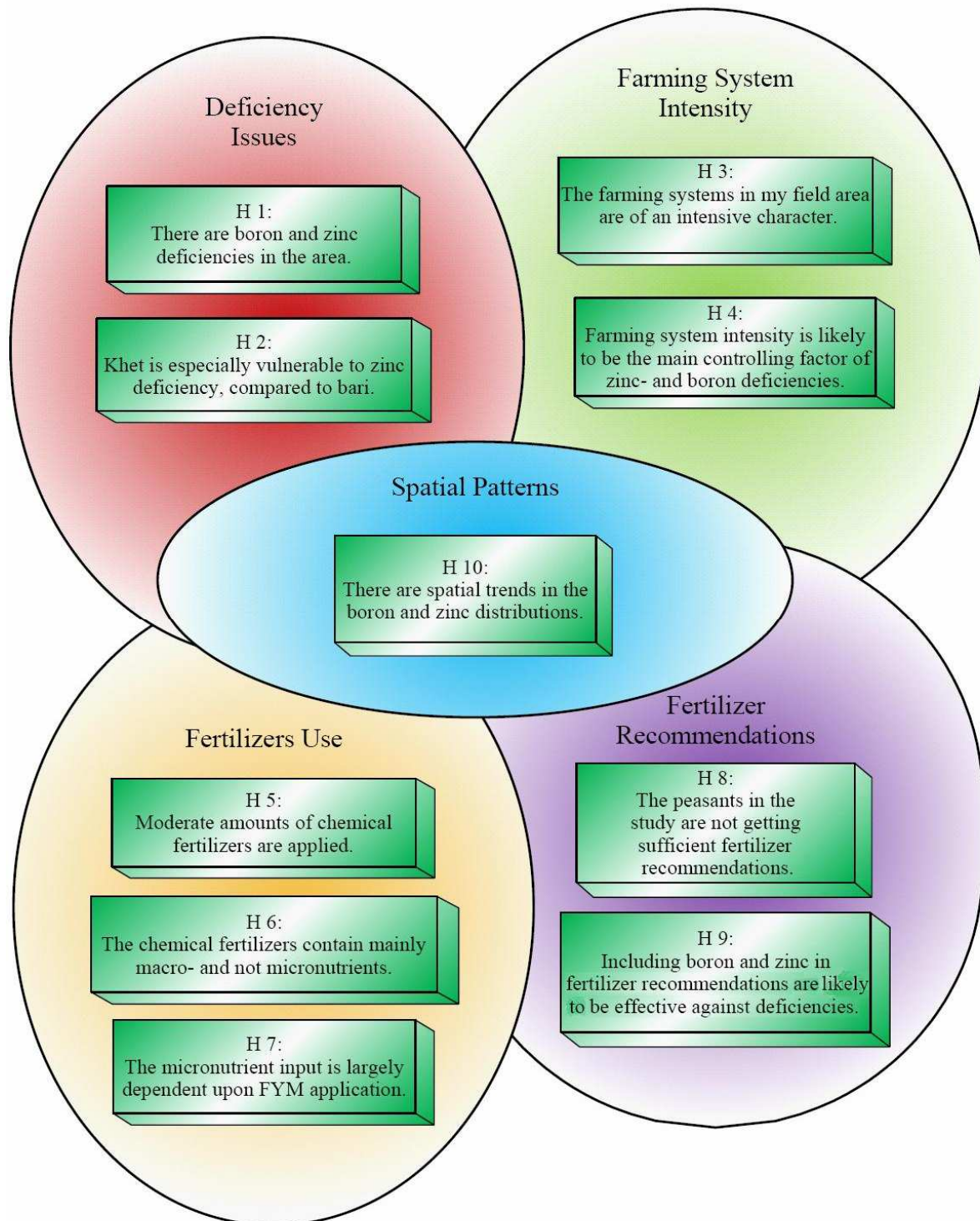


Figure 1: Graphic display of hypotheses.

1.2.1. Deficiency issues.

Values of available zinc and boron were gathered through soil sampling. As the literature search in chapter 3.1. will describe, it is recognized that zinc and boron deficiencies are widespread in Nepalese agricultural soils.

Nutrient deficiency in plants appears when the supply of the relevant nutrient is inadequate and important physiological functions and growth is adversely affected due to this (Alloway 2003). It is not straightforward to assign a general deficiency limit due to the fact that deficiency limits vary according to plant species and varieties. In addition, different soil factors are affecting how well plants are able to take up the nutrients. This will be discussed later on.

To concretize, I will establish a firm deficiency limit both for the available zinc and boron. As already mentioned, doing this is disputed and several authors have different opinions on where the limit should be. I will base my decision primarily on the work of Sillanpää (1982; 1990). Doing this, I ended up with 0,6 ppm as limit for both hot water extractable boron and DTPA extractable zinc. It should be urged that this is a general deficiency limit and may not be perfectly suited for every crop and every soil.

Hypothesis 1 (H1) claims that there are zinc and boron deficiencies in the field area. Much of my approach is based on this suggestion and I therefore do not expect this hypothesis to be falsified. As previously mentioned, boron and zinc deficiencies are very common in Nepalese soils. If the hypothesis is falsified however, I will have to try to explain why no zinc or boron deficiencies are present.

The most important quality which determines the classification of a field in Nepal is whether it can impound water or not. This is due to the fact that paddy rice only can be grown in a water rich environment. High clay level in the soil is the key factor. Soils which have this ability are generally called “khet”. In the Middle Hills, farming areas consist of some 70% khet (Turner and Brush 1987). The remaining terraced fields are called bari. These areas do not have the water impounding ability which khet posses and are often sandy and well drained. Both bari and khet are terraced, but they differ in the slopes of the terraces. Khet is

fairly level, to prevent water runoff. Bari might have a steeper angle and are built differently to obstruct soil loss, slope erosion and land slides (Turner and Brush 1987).

H2 addresses the differences of available zinc levels in bari and khet. A literature search suggests that khet is most exposed to zinc deficiency. It would be interesting to see if this is the case for my study area as well, and possibly try to identify some of the reasons for it.

1.2.2. Farming System Intensity.

The gathering of data regarding farming system has been done by interviewing the peasants (Appendix I for interview guide).

H3 tries to reveal how intensive the farming system in the field area is. This is interesting because a main nutrient extractor from agricultural soils is the crops themselves. To avoid misunderstandings, a definition of how to measure farming system intensity is needed. According to Turner and Brush (1987), one can measure farming intensity by looking at output intensity, input intensity and cropping frequency. I will not be able to look at output intensity as I have not obtained such data. The input intensity will basically be evaluated along with fertilizers (labour input will not be assessed). Farming system intensity in this thesis will therefore be connected to cropping frequencies. Cropping frequencies can be measured in annual number of crops, type of crops and the amount of time the fields lay fallow. Although it weakens the validity of the hypothesis, only the annual number of crops will be used to indicate farming intensity.

According to Blaike and Brookfield (1987), virtually all land capable of being cultivated is now taken up in the middle hills of Nepal. It would therefore be natural if the peasants in my field area are operating with a relatively intensive farming system, especially since the big city of Pokhara is just a couple of kilometres away.

The cultivation friendly climate should also indicate that an intensive farming system is likely.

H4 is a logic derivation of H3 and H1. It says that if we got zinc and boron deficiencies and at the same time an intensive farming system, there could be a connection. This hypothesis will be tested by comparing cropping frequencies and available zinc and boron levels.

1.2.3. Fertilizer use

The data on fertilizer use are collected from the interviews. Having knowledge on which type and how much fertilizer each peasant uses is of interest because micronutrient values in agricultural fields are known to be closely related to fertilizer use. In this thesis, fertilizers include organic as well as chemically produced mineral inputs.

H5, “moderate amounts of chemical fertilizers are applied”, is based on the assumption that the peasants in my field area do not apply vast amounts of chemical fertilizers, primarily because they are operating on a semi-subsistence level and therefore are involved with markets on a restricted basis. Of course, this hypothesis may be totally wrong. An indication of this is that Pokhara is very close and therefore giving the peasants more options with regards to what to sell and buy.

With “moderate amounts of chemical fertilizers” I mean moderate in proportion to the averages of the Gandaki district. The best obtainable data are from 1995 when the average was 36 kg chemical fertilizer per ha, according to Rimal et al. (1997). As these figures are more than 10 years old, it is likely that the present average is somewhat higher. Data of newer date on district levels are unfortunately hard to come by. FADINAP (Fertilizer Advisory, Development and Information Network for Asia and the Pacific - 2006) operates with an average chemical fertilizer consumption in the entire Nepal of 41 kg per ha in 1998/99, while the figures from the World Bank (2005) are 10 kg per ha lower.

H6 addresses types of chemical fertilizers that are used. Focus is especially on whether micronutrient fertilizers are applied or if only macronutrient fertilizers are used. This is obviously very relevant to zinc and boron levels in the fields.

FYM is the major organic fertilizer in Nepalese agriculture. H7 is claiming that the main micronutrient input to the fields in my study area is FYM. This automatically implies that there are little other micronutrient inputs than FYM.

Further inspections of this subject will be done through correlation analyses. This will possibly reveal connections between fertilizers and available zinc and boron.

1.2.4. Fertilizer Recommendations

These two hypotheses address fertilizer recommendations in my field area. Fertilizer recommendations can be in the form of a governmental extension service or informal relations like the local shop or neighbours. It is likely that knowledge can be a limiting factor when it comes to micronutrient issues. High quality recommendations and a working extension service could possibly be of great benefit.

In the same way as for the fertilizer- and farming system hypotheses, my data regarding fertilizer recommendations are gathered through interviews.

H8 claims that the peasants in the study area are not getting sufficient fertilizer recommendations. This assumption is based on the works of Andersen (2001; 2002), who reports of a malfunctioning Nepalese extension service. If this is the case, there is probably very little communication between the scientific scene and the field, especially in more or less peripheral areas.

The question that H9 raises is whether it is likely that including zinc and boron in fertilizer recommendations would be effective against boron and zinc deficiencies, or not. This is a question that is hard to answer firmly, but I think it is so important to discuss the subject that I am willing to do it with basis in an inaccurate hypothesis.

Including boron and zinc in recommendations could be to recommend micronutrient blended fertilizers or single micronutrient fertilizers. Even recommending increased appliance of FYM would be one way of doing it.

1.2.5. Spatial patterns

Spatial data analyses have been done in a GIS package called ArcGIS. All obtained samples were marked with GPS coordinates and spatial investigations could therefore take place.

H10 says that there are spatial trends in the zinc and boron distributions. This is a very interesting question. If we can pin point such patterns it is likely to give us indications on the underlying causes as well. Such indications could be obtained by for instance comparing farming system data with the boron and zinc spatial patterns.

1.3. ORGANIZATION OF THE THESIS

The thesis contains seven chapters. The first chapter includes the research question as well as the hypotheses.

Chapter two briefly describes the study area. Some information regarding Nepal is also included.

The third chapter is an overview of the most important theory connected to my approach. The prevailing theories on zinc- and boron deficiencies and Nepalese farming systems are in the main focus. In addition are extension services and blanket recommendations reviewed.

Chapter four is used to discuss methodical approaches as well as methodical problems experienced during the study.

Chapter five presents the data obtained during the fieldwork. It also reports on the analyses that have been executed.

The sixth chapter is used to discuss the hypotheses from chapter one against the findings in chapter five. Some findings that are not covered by the hypothesis are also mentioned.

The last chapter sums up the conclusions and the major findings in the thesis.

2. STUDY AREA DESCRIPTION.

2.1. NEPAL

Nepal is a 147,181 km² big constitutional monarchy, landlocked between China (Tibet) and India in the South-East Asia. While mainly known for its high mountains (Nepal contain eight of the worlds ten highest peaks), the country is more than just a part of the Himalayas. The lowest point is found 70 meters above sea level on the Indo-Gangetic Plains, which occupy the southern part of the country. The majority of the Nepalese people live in the Middle hills region, which is one of three major topographic belts. This is also where my study area is sited.

The political situation has been highly unstable since 2001, when the crown prince massacred the king and nine other members of the royal family, before taking his own life. In October 2002, the new king dismissed the prime minister and his cabinet for "incompetence" and less than a year later broke the "cease fire" between the Maoist- and the Government forces down. The Maoist insurgency, launched in 1996, has threatened to bring down the regime for the last ten years through guerrilla warfare.

Finally, the king allowed parliament to reconvene on the 28 April 2006 after nearly three weeks of mass protests organized by the political opposition and the Maoists.

The major exports of Nepal besides textiles are agricultural products such as ghee, pulses and lentils. Still, Nepal is a net importer of food (World Bank 2005). The agricultural labour force occupies 93% of the total work force, and this figure has been somewhat stable over the last 25 years. Fertilizer use per ha increased from 1970 to 1980, but has later decreased. Today is the fertilizer use back at the same level as in 1980 (World Bank 2005) Nepal is among the poorest and least developed countries in the world. According to CBS (2006), 31 percent of the population is living below the poverty line. The exact percentage is disputed though, and UNFPA (2005) claims it to be 42. Tourism has been an important source of foreign exchange, but due to the Maoist insurgency, tourism has decreased in the last decade. With the current peace treaty, hopes are that the number of tourists will increase in the coming years.

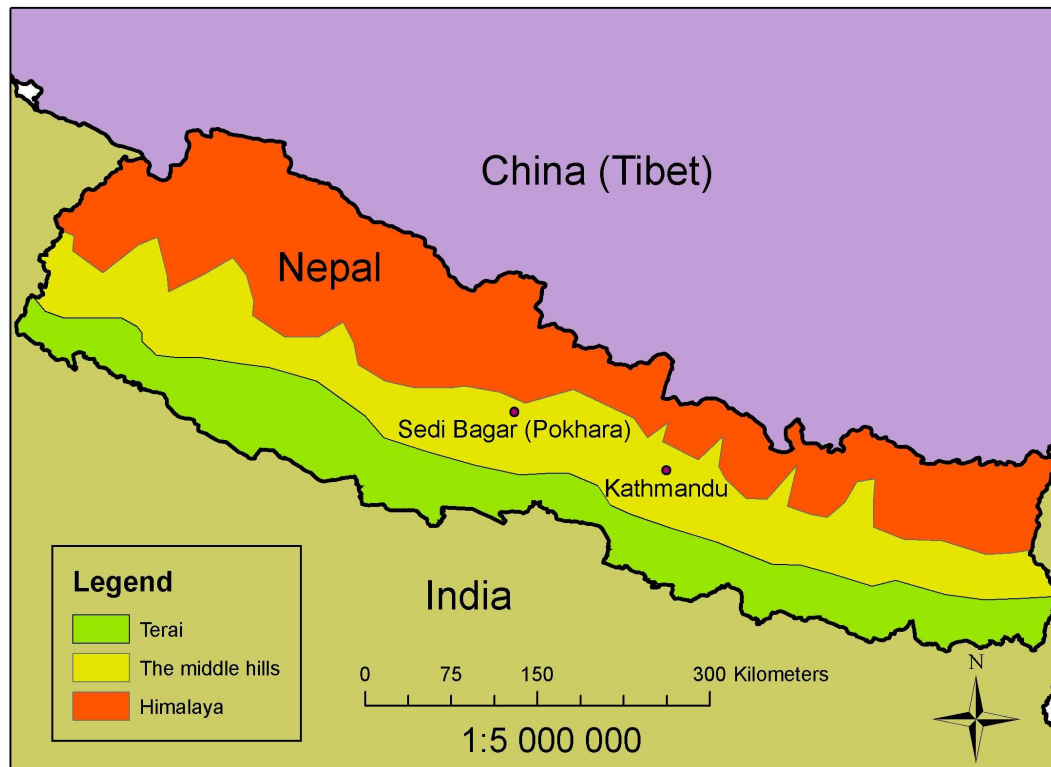


Figure 2: Map of the three main topological belts of Nepal. Adopted from Blaikie and Brookfield (1987)

2.2. SEDI BAGAR

The small village of Sedi Bagar was chosen as study area after an excursion around Pokhara and a consultation with Dr. Desh Subba and his crew at LI-BIRD (Local Initiatives for Biodiversity, Research & Development). The size of the village and the surrounding fields were appropriate and the inhabitants seemed interested in what I was doing. I was looking for an area with subsistence– or semi-subsistence farming, and Sedi Bagar fulfilled this demand.

Sedi Bagar is a small village about 3 kilometres outside Pokhara, Nepal's second biggest city. The exact coordinates are 28°13'36" north, 83°57'9" east and the area is part of the Kaski district in the Gandaki zone. The village is situated on the steep shores of the Phewa Lake (Phewa Tal) and the elevation of the houses varies between 800 and 879 meters above sea level.



Figure 3: Picture with Sedi Bagar in the centre and lower right. Lakeside, Pokhara can be spotted in upper part of the photo.

2.3. PHYSICAL CHARACTERISTICS

Figure 2 displays the three main topographic belts of Nepal. Sedi Bagar lies in the middle hills. According to Blaikie and Brookfield (1987), almost all cultivated land is terraced in this zone. That is also the case for my study area. Both bari and khet are present in Sedi Bagar, along with some small patches of vegetable fields. The size of the terraces differs according to steepness of the hillsides. Some are as narrow as a couple of meters, while others are much wider.

The study area is dominated by the open valley in the centre of figure 3. Several rivers and streams are present, some of them only carrying water in the monsoon. The valley floor is covered by fine textured alluvial deposits. Coarser soil is found in the steeper parts of the study area, mostly in bari fields. High amounts of stone are also present in the latter.

Pokhara is known to have a very humid and relatively warm climate. The annual precipitation is some 4000 mm, and as much as 80 % comes in the monsoon season (June – September). Winter is generally the driest season and is also frost free. In fact, all around the year temperatures rarely exceed 10-35 degrees (Department of Hydrology and Meteorology, Government of Nepal 2006). This sub-tropical climate is suitable for a great variety of plants and makes the growing seasons long. Three rotations each year are therefore possible with the appropriate combination of crops.

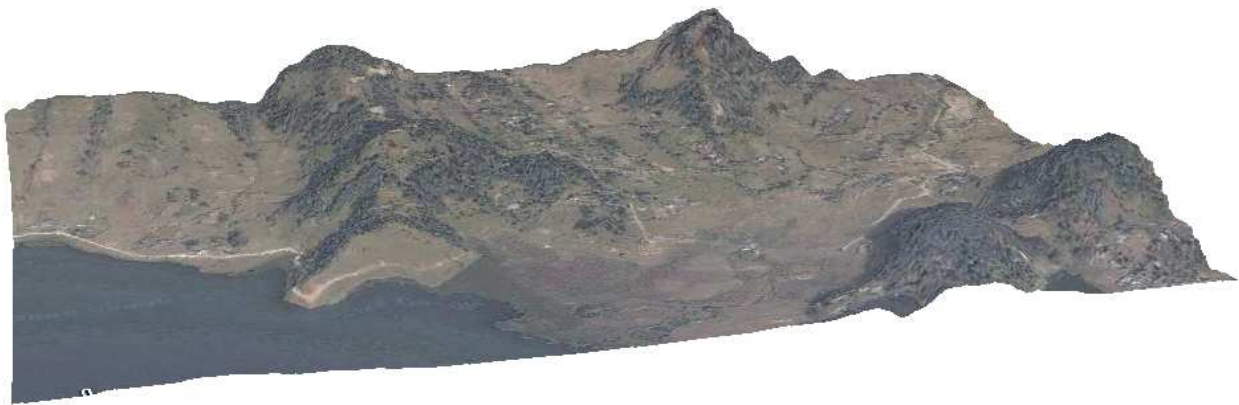


Figure 4: DEM covered with a satellite image showing Sedi Bagar in the centre of the figure.

2.4. SOSIO-CULTURAL CHARACTERISTICS

The Pokhara valley contains a lot of different ethnic groups from all over Nepal. Special for the area are the many Tibetan refugee camps established in the 1950`s. Some of the present children there are third generation refugees. The main religion in the Pokhara valley is Hinduism, but obviously Tibetan Buddhism is present as well.

Sedi Bagar has a couple of hundred inhabitants. The majority is occupied in subsistence agriculture, but some also have jobs in Pokhara, usually connected to tourism. Speaking English is a big advantage and therefore mainly younger people get these jobs. Unemployment is a huge problem all over Nepal and despite the tourism, Pokhara valley is no different. According to CBS (2006), seventeen percent of the population in the administrative area containing Sedi Bagar is living in poverty. The poverty line was drawn at 7696 Nepalese rupees in 2003 (some 100 euros). Thus, if a person has a lower annual per capita expenditure

than 7696 rupees, he or she is regarded as a person living in poverty. Seventeen is a relatively low percentage compared to the country average of 31 and the entire western hill and mountain area which had a poverty incidence of 37 percent (CBS 2006). The survey also showed that Pokhara only had two percent poverty. The relatively low poverty percentage of Sedi Bagar compared to the rest of the western hills is therefore likely to be a result of the geographical proximity to Pokhara.

Regarding the physical condition of the inhabitants in and around Sedi Bagar it seems clear that there are some issues. 49 percent are stunted and 41 percent underweight in figures from 2003 (CBS 2006). Underfeeding as well as malnutrition are possible explanations to these problems.

The main ethnic groups in Sedi Bagar are Brahmins and Chettri, which are considered as higher castes.

2.5. INFRASTRUCTURE

Most houses in Sedi Bagar are of medium size. A few are bigger, for instance the one belonging to the chief of the village. The connection to agriculture is clear, bari fields and vegetable patches are often found only a couple of meters from the houses. The animal sheds (mainly for the buffaloes) and the belonging manure heaps are also next to the houses. This is practical as it reduces carrying distances to the bari- and vegetable fields.

The village is well connected to Pokhara because of the main road curling along the northern shores of Phewa Tal. This is a tarmac road and it passes only a couple of hundred meters from the centre of the village. A gravel road connects most of the houses to the main road. The local enterprises are limited to a mushroom greenhouse facility, two tiny shops, and a small yoga centre in the northern part of the village. A few houses have access to a telephone line.

3. THEORETICAL FRAMEWORK

This chapter will try to sum up the most important theory connected to my approach. First, a short briefing on deduction and induction is given followed by a summary of relevant studies done in Nepal. Then focus is put on “the law of the minimum” and how micronutrients are affecting plant growth. The chapter continues by discussing some natural factors affecting zinc and boron levels in soils, followed by farming system dependent factors. Then, human nutrient deficiencies are briefly connected to soil nutrient deficiencies and the economic behaviour of subsistence peasants is discussed. Finally, scientific and local knowledge is mentioned along with the transference of knowledge, primarily connected to extension services and blanket recommendations.

3.1. DEDUCTION AND INDUCTION

Deduction and induction are two fundamentally different approaches to science. As there is no agreed description of *the* scientific method, both approaches will be evaluated and used in this thesis.

Francis Bacon introduced induction around year 1600. The approach is often connected to the gathering of data at an early stage in the development of a science (Holt-Jensen 1999). As data is collected, the scientist searches for regularities within the database available for him. If the scientist finds an acceptable regularity, he might call it an inductive law. As Holt-Jensen (1999) pinpoints, the obvious weakness of this approach is that you generalise from a number of observations to an assumed truth. The well-known example is “all spotted swans are white, thus all swans are white”. I operate in a small geographic area and I am taking a relatively small amount of tests. This makes induction hard to rely on, as chances are good that my results are not representative in a larger context. As previously mentioned, my work is a case study and therefore not meant to be representative for a bigger area. Still, if I created an inductive law for my study area, it would be a generalization as I only have a certain number of points where I know the data.

Deduction made its entry in the nineteenth century and is perhaps best known through Carl Popper and his critical rationalists. He argued that it did not matter how many times a theory or hypothesis was confirmed, it had to be possible to falsify it if it was to be called scientific. This was because almost any theory could be confirmed, with some imagination, multiple times. If it was falsified, however, you would have to throw it away, or at least modify it. The methodology of deduction is of quite another nature than induction. When deducting you create a hypothesis before testing it. According to Popper, a hypothesis should be tested as hard as ever possible. Still, a hypothesis can never be finally verified. This leads to the conclusion that certain knowledge does not exist. It obviously implies that deduction itself is not the certain way to go. Thomas S. Kuhn argued that even if a main theory is refuted, it is not necessarily thrown away. Only if a better or more trustworthy theory comes up, there will be a change. Holt-Jensen (1999) sums up deduction into three basic principles:

- The principle of falsification: Universal statements and theories can only be refuted, not verified.
- The principle of criticism: Scientific knowledge grows only when open to critics, trial and error.
- The principle of demarcation: The characteristic of scientific statements are that they are empirically testable, capable of refutation if they are false.

The most widely accepted way of doing research, is probably to have a deductive approach. This means that one create some hypotheses based on prior knowledge and try to test them. It includes of course a kind of inductionism, as the creation of hypotheses always are based on some imaginary regularity. This leads to the idea that science goes nowhere without induction, an idea that I fully support. I will therefore not restrain myself against using induction for what it is worth. Quite on the contrary, if I was to come up with a new trustworthy hypothesis *after* finishing my fieldwork, I would embrace it.

Even so, I will have a deductive approach from the starting point. The hypotheses I would like to test have been listed earlier. Obviously, doing fieldwork without trying to refuse some hypotheses would be more or less meaningless, from a deductive point of view.

As mentioned, Popper says that you should test your hypotheses as hard as possible. My hypotheses are perhaps a bit ambitious and it might be hard to expose them to “the ultimate test”, given my scarce recourses and limited time in field. Still, I think aiming high might be wise if I am to come up with some interesting findings.

The bottom line goal should be to have less unexplored hypotheses than when I started. In other words, closing down the possibilities and having fewer questions unanswered.

If I find regularities in the data that seem interesting, these should be investigated further, although it might be perceived as inductionism.

3.2. REVIEW OF ZINC AND BORON ISSUES IN NEPALESE SOILS

In his global study from 1982, Mikko Sillanpää investigated levels of micronutrients in soils and plants of 30 countries, among them Nepal. The purpose of the survey was to detect deficiencies and toxicities that were yet to be found, as well as getting a global view of the situation with fresh data. A big advantage with Sillanpää's study was that the same laboratory and the same procedures were used with all of the samples, although they came from different parts of the world. The results should therefore be compatible and able to give a good comparative picture of the global differences. One of the reasons why the study was done was that the author thought too little attention was drawn towards problems regarding micronutrients, compared to macronutrients (Sillanpää 1982).

According to Sillanpää, micronutrient deficiencies were severe in Nepal. Compared to the other 30 countries in the survey, Nepal occupied the very lowest position regarding boron in soils. The average value was less than 0,2 mg/l using hot water soluble extraction method. As this was a national average, and national variations often are huge, it is dangerous to generalize. Still, Sillanpää expressed: *"..widespread B deficiency, acute or hidden, is likely to exist in Nepal, limiting yields especially of those crops with high B requirement."* (Sillanpää 1982, p. 245) Also, the average zinc level in Nepal was at the bottom of the list. The situation was not as severe as with boron, but Sillanpää still expected zinc deficiency in many locations in Nepal. The national average was some 0.9 mg/l DTPA extractable soil zinc (Sillanpää 1982). In a later study, Sillanpää (1990) again demonstrated zinc and boron deficiencies at the majority of his test locations in Nepal.

Zinc and boron deficiencies in Nepalese soils have been reported frequently. I will not try to make a complete list, but illustrate with a few examples. Benjavan Rerkasem found extensive

evidence of boron deficiencies in wheat (*Triticum aestivum* L.) in Nepal, a cereal that generally have been considered to have low boron requirements. She considers the adjoining area of Bangladesh, Nepal and India as the world's most extensive area of boron deficiencies (Rerkasem and Jamjod 2004). Victor M. Shorrocks (1997) illustrates that parts of Nepal lies in a region that is exposed to boron deficiency. He urges, however, that boron deficiencies often are dependent upon local conditions.

Andersen (2002) found regional deficiencies of boron in several areas of Nepal, as well as many low and deficient values of zinc. He suggested that as much as 85-90 % of all Nepalese soils were deficient regarding boron and 30-50 % regarding zinc. During a study of micronutrient deficiencies in grain legumes, Srivastava et al. (2005) found that boron severely restricted growth of lentils, chickpeas and pigeon peas in the Inner Terai. Zinc was also a restricting factor, but not to the extent of boron. In "a soil fertility management strategy for Nepal", Brian Carson recognised both boron- and zinc deficiencies in forests and agriculture lands in Nepal. He points that this is caused by mismanagement of the soil, rather than a general deficiency (Carson 1992).

The above literature implies that Nepal is exposed to boron and zinc deficiency. Rerkasem and Jamjod (2004) suggests that Nepal is part of boron deficient region, while Carson (1992) claims that both boron and zinc deficiency in Nepal is present due to mismanagement of the soil. These two arguments are obviously not mutually exclusive, but they differ from regional to local when it comes to context.

This is one of the subjects my study may investigate. If there is a widespread deficiency, but none of the farming system factors seem to affect the level, this can suggest a regional trend. On the other hand, if for instance a lack of fertilizer input is leading to deficiency, one could say that the cause of the problem is local.

3.2.1. The law of the minimum.

The law of the minimum is usually credited to Justus von Liebig and his work from 1840; *“Die organische Chemie in ihrer Anwendung auf Agricultur und Physiologie”*. According to Ploeg et al. (1999) however, Liebig's countryman and colleague Carl Sprengel outlined the essence of the law when he published *“Von den Substanzen der Ackerkrume und des Untergrundes”* in 1828.

The law of the minimum quickly became important principle within agricultural science. It states that growth of a plant is not determined by the total amount of resources available, but by the scarcest resource. This means that plentiful amounts of one resource can not weigh up the lack of another. In practise, one should always have focus on what is most required by the plant. Some obvious requirements of plants are sun, soil, water and some atmospheric gases. However, nutrients are just as important. These are classified into macro and micro. The categorization is based on the amount needed by plants. Although the macronutrient nitrogen is needed in larger quantities than the micronutrient zinc, “the law of the minimum” still applies. Different plants have different needs, though, but a certain level of all the essential nutrients is always needed. Applying nitrogen to a zinc deficient field is not likely to boost the crop as much as applying zinc would. Focus have generally been on macronutrients, as one have thought that micronutrient level have been adequate (Sillanpää 1982). Another possible explanation to the ignorance of micronutrient issues is the huge difference between micro- and macronutrients in quantity that is taken up by plants. As much as several hundred kilos of macronutrients can be taken up per ha, while the amount of micronutrients usually is limited to a couple of hundred grams (Andersen 2006).

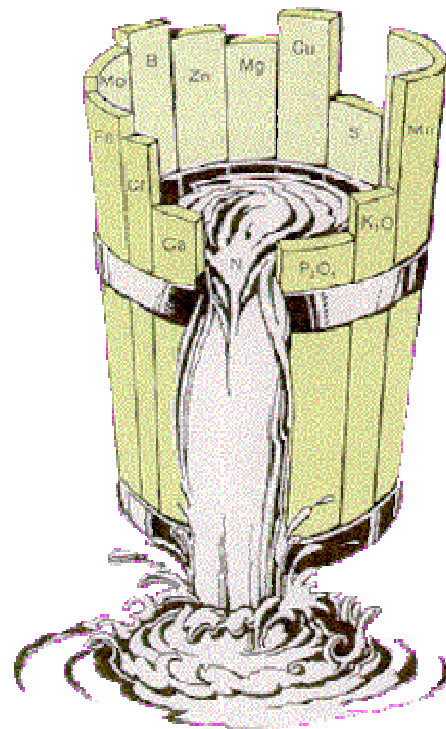


Figure 5: Illustration of "the law of the minimum" – the barrel model.

3.2.2. Effects of zinc and boron deficiency in crops.

In the same way as different plants and genotypes have dissimilar deficiency limits, they also react differently to deficiency. I will therefore try to sum up the most general and important reactions boron and zinc deficiencies cause plants.

Boron has a small, but important role in the cell wall structure of the plants. If a deficiency arises, the cell walls often experience abnormalities and stunted plants can often be a result. Problems can also arise in plant membranes. Boron deficient roots have showed lack of capability regarding phosphorus-, chloride- and rubidium uptake. Boron treatment of the roots restores the situation to normal (Blevins & Lukaszewski 1998). It seems like boron requirement is higher at the reproductive stage of the plants than at the vegetative stage. This may result in problems in pollen formation, fruiting and flowering of plants (Blevins & Lukaszewski 1998). Benjavan Rerkasem and Sansanee Jamjod (2004) reported of boron deficiency as the cause of grain set failure in wheat in Nepal. They also claimed that root length is a subject to boron availability. If there is a boron deficiency, the first response from the plant will be cessation of root elongation. Based on this information it is probably fair to say that the nutrient is vital to plant nutrition. Although boron has been known since 1923, much of the research done is still quite fresh. This may be one of the reasons for the lack of focus on boron until recent years.

The visual results of boron deficiency are many and can easily be confused with other deficiency symptoms, but they often occur at the growing points and fruiting parts of the plant. Hollow fruits have been reported and yellow or red spots on the upper leaves can also be a sign low boron uptake. Not only is it hard to distinguish different deficiency symptoms from each other, different plants have different symptoms as well. This makes the task of recognizing nutrient deficiencies by visualization even harder for the Nepalese peasants.

Zinc is a very important component of approximately 70 enzymes in plants. This results in zinc affecting various essential processes indirectly:

- Photosynthesis and conversion of sugar to starch. A deficiency in zinc can reduce photosynthesis by 50-70 % depending on plant species and severity of the deficiency.
- Protein metabolism. Might cause deficient plants to have reduced amount of proteins and disturbed concentrations of some amino acids.

- Auxin metabolism. Affects growth and may lead to dwarfing, stunting and rosetting.
- Pollen formation. Reduces pollen production and causes grain positions to be empty in self-pollinating cereals.
- Maintaining biological membranes.

(Alloway 2003)

As briefly mentioned, different plants and genotypes do not always share the same sensitivity to micronutrients. In the case of zinc, it seems like bean, fruit trees, maize and rice are among the most sensitive plants. This lack of micronutrient efficiency more easily leads to severe deficiencies in some plants.

Typical symptoms of zinc deficiencies are:

- Chlorosis. Because of zinc being immobile in the plants it is often the younger leaves that become victim of chlorosis. The midrib is turning yellowish, and later into a darker colour. Brown spots may appear on older leaves. (Neue et al. 1998)
- Stunting. This is a consequence of the reduced auxin metabolism.
- Rosetting, malforming and dwarfing of leaves. These three symptoms are results of stunting. Rosetting happens when the stems on a plant fail to elongate and as a result the leaves cluster together (Alloway 2003).

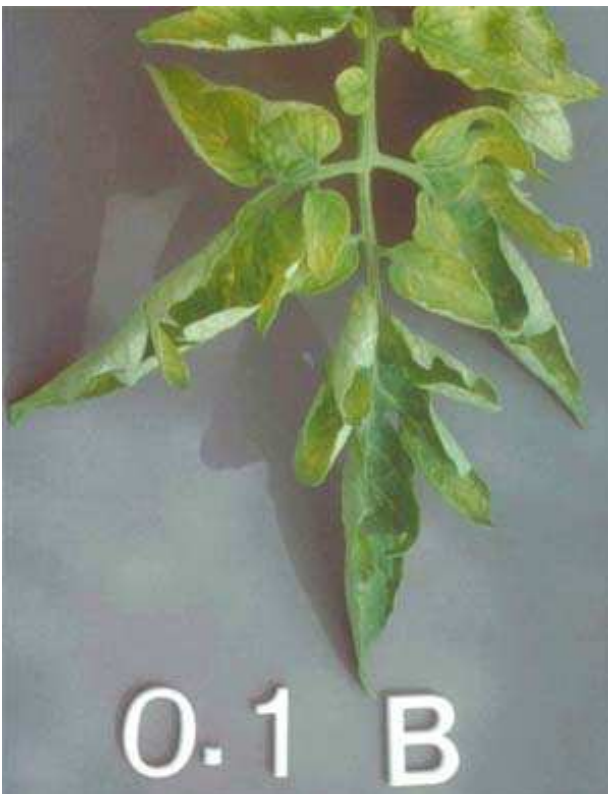


Figure 7: Visual symptoms of boron deficient tomato plant.
(www.plantphys.net) – 20/8-06



Figure 6: Visual symptoms of zinc deficient tomato plant.
(www.plantphys.net) – 20/8-06

It should also be mentioned that toxicity can be a just a big problem as deficiency. In Nepal is boron subject to such issues. As with deficiency, plants differ in sensitivity to toxicity. This induces problems in the very common rice-wheat rotation. Wheat is known to be sensitive to boron deficiency, while rice is sensitive to boron toxicity (Andersen 2006). Given the close range between boron deficiency and toxicity, finding the right balance can be very demanding, requiring thorough soil testing and suitable fertilization. It is indeed a bit ironic that the peasants should be aware of boron deficiency in the winter season (during wheat cultivation) and boron toxicity in the summer season (during rice cultivation).

This chapter demonstrates that both boron and zinc are of great significance to plants, and reinforce the assumptions drawn from “the law of the minimum”; saying that *all essential* nutrients are of vital importance.

3.2.3. Natural agents affecting zinc and boron levels of the Nepalese soils.

Obviously, my main focus is not all the natural agents affecting micronutrients. However, a brief introduction is needed to understand more of the broad picture. The most basic natural processes will therefore be reviewed here, while the farming system impacts will be spotlighted in a later section.

Few argue the fact that geology often is a major piece of this puzzle (Carson 1992). Bedrock is weathered and nutrients released into the soil and subsoil water. This is an important factor, but very difficult assess. It is hard to determine the exact micronutrient levels of the parent material, especially if it is covering a large area. The micronutrient concentrations can also vary within a given rock type. It seems like basaltic and shale rocks contain more zinc, 100-120 mg per kg, compared to limestone and sandstone with only about 20-30 mg per kg (White & Zasoski 1999). Regarding boron, especially igneous rocks, like gneiss and granite, but also metamorphic rocks seem to have low concentrations. Some sedimentary rocks, especially marine shales, are the opposite (Shorrocks 1997, Mortvedt et al. 1991). It is important to remember that micronutrient concentrations in rock differ greatly even within the same rock type. Age have significance as well. Bedrocks of old landscapes are assumed to have lower micronutrient concentrations than newer. It is therefore expected that low soil micronutrient levels will be found in old landscapes where bedrock micronutrient levels are low (White &

Zasoski 1999). Geology maps of my field area are hard to find. Department of Mines and Geology (DMG) in Nepal is not easy to get in touch with and my only source of geology maps is the German Bundesanstalt für Geowissenschaften und Rohstoffe (BGR). They did geology mapping in Nepal between 1988 and 2004 and have produced some low resolution soil and geology maps of the Pokhara Valley (figure 24 and 25). As these maps have quite limited quality, it is hard to put each of my samples into one of the geology or soil categories on the maps. They will therefore be used more on a general basis, showing which geology and soil types are present.

Climate and weathering is known as factors affecting micronutrients. Very generally speaking, physically and chemically active climate causes the soil to contain less micronutrients (White & Zasoski 1999). Erosion can be caused both by wind and precipitation. Wind erosion is most effective when vegetation cover is scarce or not existing. Small grains of soil are carried away, decreasing the soil depth and also metal micronutrient levels. Wind erosion should not be a major subject in Pokhara valley, though. As for water, the situation looks more serious. Because of the steep hills and massive precipitation during the monsoon, it is logical that a lot of soil will be carried “down the drain”. Zinc is exposed to the threat of erosion, due to it being tightly bound to the soil. However, because of vegetation cover and widespread terracing, the erosion is not as bad as one might think (Blaikie & Brookfield 1987).

Still, the water may have a heavy impact. Leaching is a problem attached to the more soluble micronutrients, such as boron. These are negatively charged and therefore does not sorb easily to clay particles. Data on leaching of micronutrients are scarce, but it is assumed that leaching losses of boron can be heavy and it will be maximal on coarse-textured soils (Shorrocks 1997; Brown 2004). Geographical positions in proportion to nearest sea may also be of importance. As sea water normally contains some 4.5 mg boron per kilo, precipitation originating from sea water may lead to higher soil boron values than precipitation originating from fresh water (Shorrocks 1997). This is not likely to be an important factor in Pokhara, though, as distance to closest sea is substantial.

Everywhere, particles sent to the atmosphere by industry processes, such as zinc, are deposited back to the earth. This is more or less known as pollution because it is likely to bring more negative effects than positive. However, it may cause zinc levels in soils to

increase. Still, it is not likely that these amounts of zinc can overcome a deficiency (Alloway 2003). Pollution of this kind is not likely to take place in my field area in Pokhara, due to limited industry.

As mentioned, the geology of an area affects micronutrient levels of the soil. Obviously, geological deposits such as clay does not always stay put where they were weathered from the rock. Water, ice and wind may move them around. Alluvial deposits are important factors regarding micronutrient levels. They cause a certain diversity of geological input and make it even harder to distinguish where the micronutrients came from (White & Zasoski 1999).

This sums up some of the most central natural agents affecting micronutrient concentrations in soils. Extraction by plants will be reviewed along with the farming system. Levels of micronutrients in the soil are of course important and interesting. However, since farmers tend to harvest resources from plants, it seems like a good idea to focus on the amount of micronutrients that are available to plants. As implied, soil micronutrient concentrations and plant available micronutrients are not identical. According to Sillanpää (1982), soil factors regulate how much nutrients plants possibly can take up. I will here list the soil factors most relevant to zinc and boron availability.

pH. When measuring soil pH, you assess the soil solutions alkalinity and acidity. Soils are often referred to as being neutral, acidic or basic (alkaline). The pH range stretches from 0,1 to 14. Seven is neutral while the closer you get to zero the more acid the soil is. Fourteen is the ultimate basic solution. The scale is logarithmic which means that each unit on the scale is ten times more acid than the unit over it and ten times less acid than the unit beneath it. Soil pH is given by the amount of acid- and base forming ions in the soil. There are some factors known to influence soil pH. Parent material may be a major contributor to either acid or basic conditions. For instance, granite is known to cause acid conditions, while calcareous rocks are likely to produce basic soils. High amounts of precipitation are often

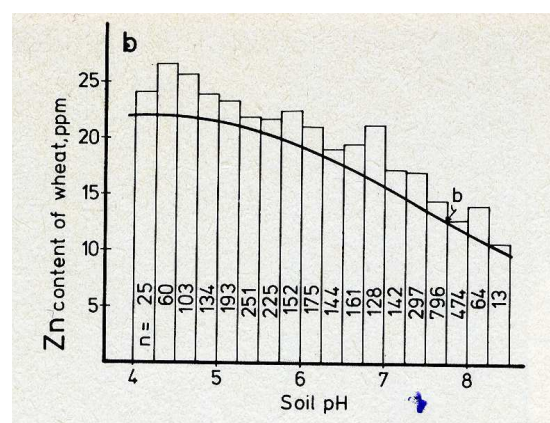


Figure 8: Shows the correlation between low pH and high zinc content in wheat.

connected to acid soil pH. Precipitation is acid itself, and in addition, it causes leaching of base cations which alter the ion balance toward a more acid environment (Brady and Weil 2004). This should certainly be the case for Pokhara Valley, which receives a massive amount of precipitation. Acid soils are therefore likely to occur in the field area.

Generally, pH is the variable affecting micronutrient availability most. This goes for zinc as well. Zinc availability rises with decreasing pH (Sillanpää 1982, Alloway 2003, Mortvedt et al. 1991). Shorrocks (1997) claims that pH have little practical influence on boron availability. Sillanpää (1982) found a good correlation between pH and boron, but suggests that this is an indirect effect of the cation exchange capacity of the soil. His opinion on this is disputed, though. Gupta (1993) claims that boron availability is severely affected by pH. According to him, boron becomes less available to plants with increasing solution pH.

Cation Exchange Capacity (CEC). Soil particles may have positive- or negative charges. Positive charged soil particles attract negative charged ions, called anions. The negative soil particles attract cations, which are positively charged. Generally, soils have more negative charged soil particles than positive, and the total negative charge is called cation exchange capacity. The CEC tells us something of how much nutrients the soil can hold by charges. These nutrients are exchangeable and can therefore be taken up by plants. Clayey soil is an example of a soil with high CEC, although CEC vary within different clay types. Boron availability is affected by CEC. According to Sillanpää (1982), there is an increase in available boron from CEC 0-20 me/100g. A further increase in CEC leads to a decrease in available boron. CEC only moderately effects zinc availability (Sillanpää 1982).

Soil texture. Soil texture is the relative amount of sand, silt and clay that soils consist of. As we have seen with the example of clayish soil, CEC is dependent upon soil texture. Fine-textured soils are often able to hold larger amounts of nutrients as they have higher surface area, and thereby more binding places for nutrients than coarse-textured soils Boron seems to have optimum availability in mid textured-soils and lower availability at the fine- and coarse textured soils. Zinc is the other way around; Lowest availability in the mid-textured soils and higher in the fine- and coarse textured soils. Soil texture is also known to affect the decomposition rate of organic matter. Sand and silt soils have an average to high decomposition rate, while clayey soils have a slow rate.

Organic matter content. Organic matter is materials which are or have been decomposed by soil organisms, as well as living organisms in the soil (Brady & Weil 2004). As well as releasing organically-bound nutrients, they also affect nutrient availability. According to Mortvedt et al. (1991), increasing organic matter increases organic and exchangeable fraction zinc, which means that more zinc are available to plants. Obviously, organic matter content is very closely related to organic carbon content. Thus, increasing organic carbon content increases available zinc (Sillanpää 1982; Chaudhary and Narwal 2005).

Boron does not seem to be as affected by organic carbon content as zinc (Sillanpää 1982). Still, it does have a positive influence on boron, according to Gupta (1993).

Water / Moisture. Regarding boron availability, drought plays a major role. It seems like drought stress are able to induce boron deficiency. The cause of this is disputed. One proposed reason is that the lack of water restricts mineralization and availability to plants of organically bound boron in soils. (Mortvedt, et al. 1991) As mentioned earlier, boron deficiency reduces root growth of plants. This may increase the drought problem due to the plants not being able to stretch further for water. This is again likely to lead to a more severe boron deficiency.

Zinc availability may also be connected to water issues. One theory is that crops cultivated in flooded fields (mainly rice) are more vulnerable to zinc deficiency, because of low zinc availability (Neue et al. 1998; Alloway, 2003; Mortvedt et al. 1991; Timsina & Connor, 2000). The most obvious reason is perhaps that zinc is has the highest mobility in freely drained soils (Alloway 2003). However, there are several proposed causes to why waterlogged soils affect zinc availability. According to Neue et al. (1998), acid soils experience rising pH while being exposed to anaerobic conditions. As commented earlier, rising pH generally causes lower zinc availability. Alloway (2003) claims that water logging causes formation of insoluble zinc compounds. As insoluble zinc can not be taken up by plants, it becomes unavailable. An example of such a compound is ZnS (Timsina & Connor 2000). The significance of ZnS-formations has been questioned, though (Mortvedt et al. 1991).

Also, *“increased availability of Ca, Mg, Cu, Fe, Mn and P on prolonged submergence depresses zinc availability and uptake”* (Neue et al. 1998; 140). This means that the

abundance of some nutrients due to flooding can reduce the plants ability to take up zinc. It is estimated that 50% of all rice soils are affected by zinc deficiency and water logging is one of the common reasons to explain this (Alloway 2003).

My samples are dried and should therefore not be subject to water logging issues. One should expect the plants cultivated during the monsoon to be exposed to these problems, though.

3.3. PLANTS AND FARMING SYSTEM

In this study, available zinc and boron values will be investigated and connected primarily to farming system factors.

Obviously, farming systems are different in a space and time context. I will therefore focus on the “typical” Nepalese, semi-subsistence farming practice which I find in my study area. I will in this section try to show the importance and function of nutrient balance, as well as investigating which components a farming system consists of. Figure 9 illustrates the picture I drew of the Nepalese farming system before I did my fieldwork. A question mark was the degree of connection between the subsistence peasant and the local market. This is important because it influence the type of crops peasants tend to grow. If involved in a market, it gets important to cultivate crops that will give nice revenue when sold. These types of goods may differ from what the peasant would have grown if he was merely operating on a subsistence basis. Money in the pocket and a market within reach also mean that it is possible to buy goods. This leads to the possibility of applying chemical fertilizer. It may also reduce the need for certain crops to be cultivated, as these can be bought. Use of forest resources naturally differs as the distribution of forest varies in space and possibly also in time. It is claimed that the areas of forest have decreased a lot in Nepal since 1950 (Carson 1992). This view is not shared by all, however. Figure 9 should be seen as a thematic overview map of the remainder of chapter 3.2. It will therefore not be discussed further here.

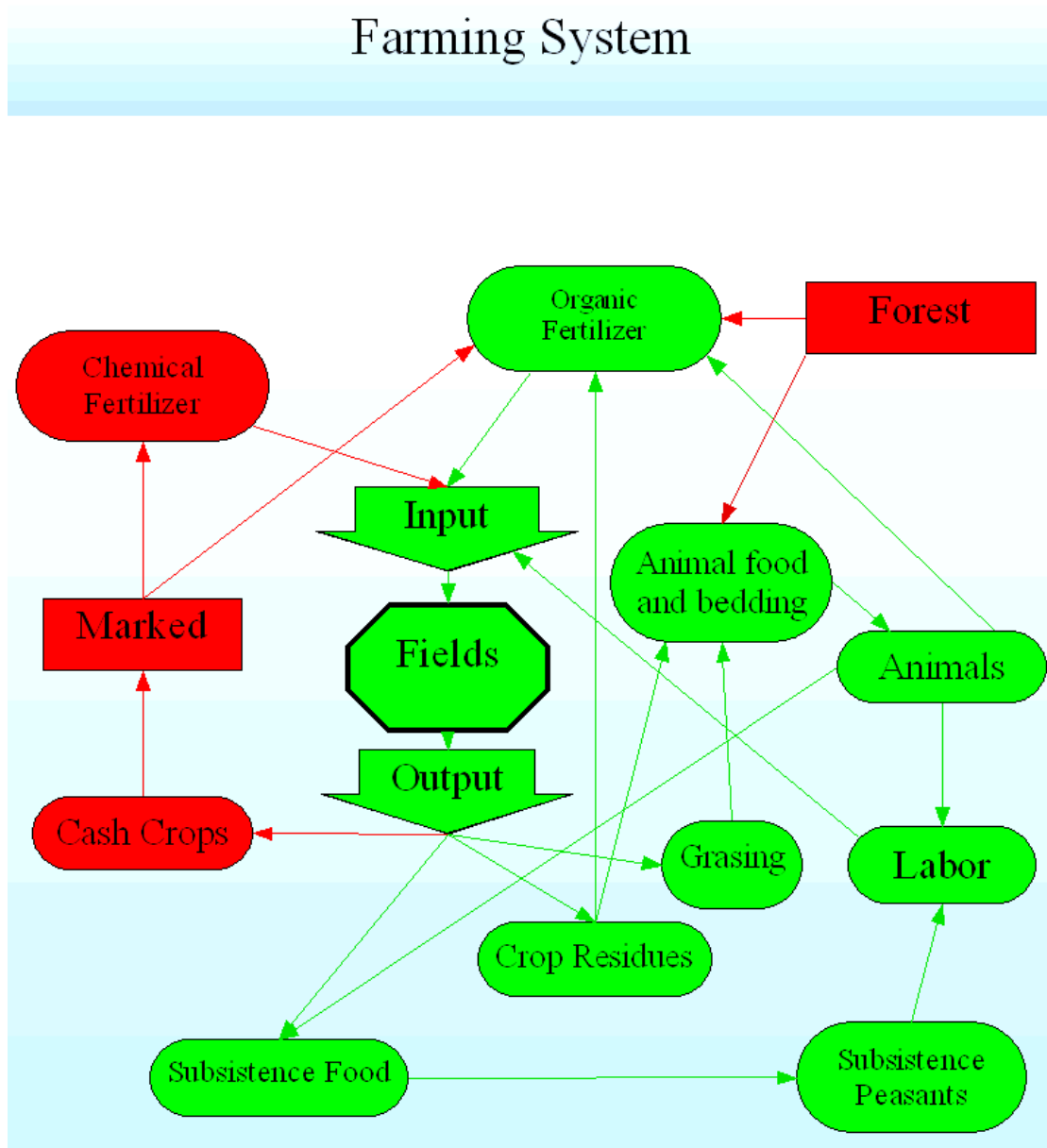


Figure 9: Green bubbles illustrate more or less universal mechanisms in the Nepalese subsistence farming system. Red mechanism are dependent upon various conditions and can not be expected to be found everywhere in Nepal.

3.3.1. The nutrient budget.

“..it can be stated unequivocally that a yield limiting nutrient deficiency will occur if the input of a plant available nutrient into an ecosystem is less than the export of that nutrient from that ecosystem.” (Brown 2004)

The nutrient budget idea is as logic as it is simple. Mated with Liebig`s “law of the minimum”, we get a reasonable concept; If more nutrients are withdrawn from a soil system than supplied, yields will at some time be diminishing. Put in other words, sustainable agriculture can only be maintained if the inputs are equal or higher than the outputs.

3.3.2. Nutrient output

“Micronutrients are becoming increasingly important to world agriculture as crop removal of these essential elements increases.” (Brady 2004)

Some natural nutrient input and output sources have already been reviewed in section 3.1.3. The following are to a large extent farming system dependent. The basic concept of cultivation is to produce and withdraw something from the field. This includes of course macro and micronutrients. Harvesting cultivated products is the main nutrient extractor in most agricultural environments. The amount of nutrients withdrawn depends upon what is grown and how many crops the farmer squeezes in on a year. This will be looked at later.

A side effect of harvested crops is the removal of crop residues (Brown 2004). Crop residues are generally the parts of the plants which are not refined. Still, crop residues are often transported away from the field, leading to a nutrient output. The residues are of course frequently used as animal fodder or bedding and re-supplied to the fields through farmyard manure (FYM) or organic fertilisers. According to Prasad & Sinha (2000) as much as 60 % of the zinc extracted under a rice-wheat cropping system can be recycled if the straws are returned to the field. This study was made in calcareous soil in Bihar, India.

3.3.3 Nutrient input - Organic Fertilizers

As well as with output, the peasant has options regarding the input of his fields. When it comes to nutrients, these options are different forms of fertiliser. Traditionally, Nepalese peasants have used various sources of green manure and farmyard manure (Manandhar and Khanal 2005). Green manure can be applied in a “cut and carry” manner. Logically, “cut and carry” is cutting down plants and carrying them home, where they often are used as animal food, animal bedding or mixed into the compost heap. When buried, the plants will break down and nutrients and organic matter will be released. Plants used for such green manure are generally from the forests, as some special forest plants have high nutrient content. “Cut and carry” is maybe an indistinct expression, as much of the plants are forest litter found on the ground. Unfortunately, some claim that forest areas have decreased a lot since 1950 (Carson 1992). This may have led to the fact that there is less available green manure for the farmers. (Turner & Brush 1987) In addition, the government of Nepal has imposed restrictions on collecting green material from the forests; due to the deforestation problems Nepal is experiencing (Tiwari et al. 2004). The discussion around “the disappearance” of Nepalese forests is disputed, however. Gilmour (1988) claims that the introduction of agro-forestry has increased the forest areas in the last decades.

Green manure can also be used in-situ. This means that the farmer will grow a certain plant in his field, which will be cut and buried in the same way as the material he got from the forest (Ministry of Agriculture and Co-operatives 2004). These plants used for in-situ green manuring are special, as they have some abilities most other plants lack. The atmosphere consists of some 79% nitrogen and the mentioned plants can fixate this nitrogen. An example is Azolla (Anabaena Symbiosis) who uses its symbiotic relationship to the blue-green algae (Anabaena Azollae) to take up nitrogen from the air. Azolla can produce 2 to 4 kilos of nitrogen per hectare per day under optimal conditions (Lumpkin & Plueknett 1985). Soya beans have the same ability to fixate nitrogen, but in that case it is the Rizhobium Bacteria that does the work (Lumpkin & Plueknett 1985). As in-situ green manure basically affect nitrogen in soils, it is not very relevant to boron and zinc.

Farm Yard Manure (FYM) is muck from domestic animals, sometimes mixed with various forms of compost. Andersen (2001), reports that FYM (maal) is concerned to be “the real thing” in his study area in the Nepalese Middle Hills. However, Timsina & Connor (2001)

regard FYM to be relative low in nutrient concentration. They state though, that this depends greatly upon source, conditions and duration of storage. Following composting, concentrations are generally greater, but amounts are less. Composting techniques are often poor among small scale farmers and may lead to development of white grub pest as well as FYM not reaching the thermophilous stage (Andersen 2001). As mentioned, FYM is manure from domestic animals. Getting enough food for these animals is an increasing problem and often leads to a decrease in livestock numbers per farm (Tiwari 2004; Sherchan et al. 1999; Khanal et al. 2005). This is again often related to the “disappearance of forests” and the government policy of prohibiting farmers to gather from these. Whether the forests are disappearing or not, in most cases farmers feed their animals with straw from their own crops. Some have also a slice of available pasture, due to fallow season. The result of this is a lack of nutrient flow from the forests to the fields, because the animals only eat food that has been grown in the fields. It has been suggested that this may affect the nutrient content of the manure and therefore the nutrient status in the fields (Blaikie & Brookfield 1987; Turner & Brush 1987).

There is an initial rapid release of nutrients from composted FYM applied to soil together with a more resistant portion that is released slowly to provide residual nutrient benefit. (Timsina & Connor 2001) As mentioned, is it hard to say something general about nutrient concentrations of manure as it differs greatly. What seems clear is that application of FYM increases organic matter content of soils (Edmeades 2003; Rekhi et al. 2000), which is known to improve soil structure properties (Carson 1992). The role of FYM should therefore not be underestimated. Chemical fertilisers are important, but FYM is needed in rice-wheat agriculture systems to keep fertility at a good and stable level, according to Regmi (2000) and Prasad & Sinha (2000). The latter study suggests that addition of organic manure and crop residues may increase available zinc from deficient to sufficient levels.

In a long-term study of a millet–wheat rotation in India, Chaudhary and Narwal (2005) found that applying FYM increased available zinc to a large extent. They explain this with the zinc mineralization from FYM and the chelating effect FYM contributes with. According to Carson (1992), a peasant selling from his compost pile is a sign of ultimate desperation, as it is well recognized that his next crop solely depends on that compost.

Using animal bedding is another way of increasing the nutrient flow to the fields. Straw is used in the animal pens to trap urine. Then the bedding is mixed with FYM in the compost heap or pit (Timsina & Connor 2001). This leads to a more rapid breakdown of organic matter. In his survey in the Koshi Hills in Nepal, Andersen (2001) found that some farmers only used animal bedding during the monsoon, while others used it all year. The divide was reflected in soil nutrient levels, especially for zinc. Using animal bedding all year gave generally higher values.

Poultry manure is a good fertilizer which may be bought some places in Nepal. Andersen (2002) reports that farmers from Siduwa buy poultry manure transported all the way from the big producers in Terai. Poultry manure is effective because of its rapid mineralization. Still it may have a good residual effect which will last for at least a couple of years (Timsina & Connor 2001).

3.3.4. Nutrient input - Chemical Fertilizers

“Even today, the majority of fertilization practiced throughout the world, focuses on N, P and K and largely ignores plant demand for the remaining macro and micronutrients except where a chronic deficiency is identified. Ultimately, this unsustainable approach to plant nutrition will result in a depletion of soil reserves, increased incidence of crop nutrient deficiencies and crop yield depression.” (Brown 2004, p. 3)

The mentioned organic fertilizers from the latter section have traditionally been the main nutrient inputs for the Nepalese peasant to rely on. However, input in modern agriculture has changed towards more use of chemical fertilizers. This trend is increasing in Nepal as well (Carson 1992). Still, compared to the industrialized world, chemical fertilizers are not used to a large extent at all. Nepal’s consumption is also lowest compared to the other countries in South Asia (Andersen 2005). Especially small scale subsistence peasants rely on FYM combined with small amounts of inorganic fertilizers (Timsina & Connor 2001).

The effects of applying chemical fertilizers are scientifically well known. As mentioned earlier, different plants and different soils do not have the same requirements regarding nutrients. Thus, fertilizers differ as well. Fertilizers are often developed and produced to

support a certain farming system, crop or soil type. Some are typical macronutrient fertilizers like DAP (Diammonium Phosphate), which generally supply relatively large amounts of some macronutrients, but not much more. Others are macronutrient fertilizers with some added extra micronutrients. These fertilizers are often more specialised to a certain crop or soil type. Unfortunately, they do not exist in the Nepalese market. There are also more general micronutrient fertilizers which aim to supply a range of micronutrients at the same time. Finally there are single-nutrient fertilizers. These are developed to contain one nutrient at a very high concentration. An example is zinc sulphate monohydrate. This fertilizer may contain some 35% zinc content, which is very high considering zinc is a micronutrient (Rattan 2004).

Data on chemical fertilizer use in Nepal is not extensive, but it seems to be some general patterns. As mentioned, the largest amounts of fertilizers are used by big, commercial farms. These are generally concentrated in the Terai area, close to the Indian border. The different types of fertilizers being used by Nepalese subsistence farmers often boils down to urea and DAP (Andersen 2003). DAP contains nitrogen and phosphorus, while urea has a high concentration of nitrogen only. Brown (2004) urges that there is an overall unbalanced fertilizer strategy in the world today. He claims that too much focus is on the NPK-fertilizers, (nitrogen, phosphorus and potassium) and that this leads to crop nutrient deficiencies and crop yield depression. Single or mixed micronutrient fertilizers do exist in the Nepalese market. These include Borax, Microplex, Zinc Chelate, Zinc Sulphate, among others (STSS 2000). Such fertilizers basically go under the term “vitamin” among Nepalese farmers (Andersen 2002). This extremely broad definition does not say anything about content, though. Mixed fertilizers do not seem to be used in Nepal. The Finnish national development aid organisation (FINNIDA) in cooperation with the Finnish fertilizer producer KEMIRA, developed two special made fertilizers for a large area around Kathmandu. The two fertilizers consisted of: N:P:K:S:B:Zn, with a ratio of 20:4:5:2:0,3:1 for general crops and: 20:6:10:3:0,5:3. for rice in particular (Andersen 2003). The basis of the fertilizer development was an unpublished mapping project by Sippola and Lindstedt, carried out in 1994. It showed widespread deficiencies in boron and zinc. The unknown amount of fertilizer shipped and handed to Nepalese farmers was said to be a great success. Unfortunately, the whole project was abandoned and never evaluated, due to a breakdown between the donors and the Ministry of Finance in Nepal (Andersen 2003). The unbalanced fertilizer practise that Brown (2004) discusses is backed by Manandhar and Khanal (2005). According to them, only 15 percent of

the Nepalese peasants use fertilizers containing secondary macronutrients (not nitrogen or phosphorus) or micronutrients. The percentage is likely to be lower in the Hills, as average fertilizer usage is higher in Terai than in the Hills.

Reported reactions from Nepalese farmers on chemical fertilizer use are that it increases crop growth. But there are other effects as well. Complaints have been raised due to the soil getting hard, cloddy and difficult to till (Carson 1992; Tiwari 2004). The moisture-retention capacity is said to be reduced, possibly leading to floods or drought. Also, crops tend to decline after a period of high production due to applied chemical fertilizers (Carson 1992).

These remarks correspond to some extent with the scientific view. The soil getting cloddy and hard to till can be explained by a more rapid breakdown of soil organic matter (Andersen 2001). Prasad and Sinha (2000) urge that chemical fertilizers or organic fertilisers alone can not keep crops sustainable in an intensive rice-wheat cropping system. They believe integrated nutrient management, including incorporation of crop residues is the best way to keep up yields. This view is shared by Sherchan et al. (1999) and Carson (1992). The latter reports of drastic decline at the end of the period when nitrogen fertilizer is used exclusively over ten year. Crops declined as well when nitrogen and phosphorous fertilizers was used together over the same period, although not as drastic. *“Although it should have been apparent from the start, it is now recognised that an important synergistic response occurs when the right proportions of chemical and organic fertilizer are used. There is a role for both organic and inorganic fertilizers in Nepal...”* (Carson 1992, p. 25) In areas suffering from serve micronutrient deficiencies it is argued that even a combined application of NPK chemical fertiliser and FYM will not be sufficient. In these cases, input of the lacking element must be added to the soil in special (Andersen 2003).

The extent of chemical fertilizer use in Nepal is still very small compared to most other countries. Until 1997, Nepalese peasants got their chemical fertilizer supplies from the state owned AIC (Agricultural Inputs Corporation). Since then, the market has been opened up and a lot of private actors have started importing fertilizers. However, this liberalization is said to bring down the overall quality of the goods. In general, there seems to be a great deal of uncertainty regarding the quality of the fertilizers on the Nepalese market. The District Councils together with the Fertilizer Unit at The Ministry of Agriculture have the responsibility of checking the fertilizer market, currently flooded by low quality fertilizers

from India. This seems like a very hard job as the economic situation is often very difficult inside the administrative agencies, as well as for the peasant choosing his fertilizers.

As mentioned, the reported general trends are that peasants, and especially the poorest ones, only apply macronutrient fertilizers (if any) to their fields. The two most commonly used are Urea and DAP. Andersen (2001) did a small test to see if DAP on the Nepalese market contained micronutrients (desirable or undesirable) as well as the promised macronutrients. He found that the macronutrients checked out fine and that there were no toxic elements. His samples did not contain any noteworthy amounts of micronutrients, except for one sample containing 2 % manganese. This indicates that DAP is not suitable to cope with micronutrient deficiencies. Quality of fertilizers is especially important regarding the issuing of blanket recommendations, which will be discussed later.

The general quantity of fertilizers in Nepal is improving, due to the liberalization of the market. Still there are problems regarding availability. Communications in rural Nepal are poorly developed and this causes problems for the peasants living far from roads or a fertilizer store. According to Sherchan (1999), a majority of the hill farmers do not have access to chemical fertilizers due to their geographic location or economic situation. Andersen (2001) found that fertilizer use was lower at the farms where it had to be portered 4-6 hours compared to farms where portering was unnecessary. This theory is backed by Carson (1992), who says that 95% of all chemical fertilizers used in Nepal are within a short distance to an existing road network. Andersen claims that micronutrient fertilizers should not be as vulnerable of distance to nearest road, though, because they generally are needed in smaller quantities. Instead, he thinks that lack of knowledge is the counteracting force regarding use of micronutrient fertilizers.

According to MoAc (2000), the following range of micronutrient fertilizers was available on the Nepalese market in year 2000; Surya Zinc, Agromin, Microplex, Graficon, Zinc chelate, Fertimin Z, Zinc Sulphate, Borax, Boric acid and Vagimax (Manandhar and Khanal (2005) for a complete summary of chemical fertilizers in Nepal). This suggests that it is possible for most peasants to acquire micronutrient fertilizers if they would like to and have the means. Of course they would also need some knowledge about the subject. This will be discussed in chapter 3.5.

3.3.5. Annual rotation cycles.

What peasants grow and when they do it obviously differs from place to place, but may also vary within a smaller area. Still, there are general trends. The most important factor in the Nepalese rotation cycles is the monsoon rains. Rice (*Oryza sativa* L.) is planted on khet, when the monsoon sets in. The rice-wheat farming system is by many considered the most widespread in this region of the world. As mentioned before, rice cultivation requires a certain amount of clay, so this rotation cycle is preferably grown on khet. Although not as common, there are other rotation cycles as well on khet. Turner and Brush (1987) report of rice-potatoes, rice-fallow, rice-rice and rice-maize systems. Also, some places support a pre-monsoon crop in addition to one rice- and one wheat crop. This could be early rice, mungbean (*Vigna radiata*), cowpea (*V. unguiculata*), dhaincha (*Sesbania* spp.), jute (*Corchorius* spp.), maize, mustard (*Brassica juncea*), sweet potato (*Ipomoea* spp.) or potato (*Solanum tuberosum*). Because diversity is important to the subsistence farmers, mixed cropping is used in some systems. Mustard is often grown together with another crop, for instance wheat (Timsina and Connor 2001). This is usually called intercropping. Bari is known to support one, two or three crops each year and one of these is almost certain to be maize. Others may be millet (*Eleusine coracana*), wheat, mustard and rice (Rice cultivation demands *a lot* of precipitation as bari is not irrigated). Soybeans (*Glycine max*) are often grown on the terrace risers at the same time as the latter two.

The rotation cycles have changed over time. According to Giri (1997), Nepalese peasants often monocropped tall rice varieties in a rice-fallow sequence before 1960. Around this time, input responsive, disease and insect tolerant, high yielding varieties of rice and wheat was introduced. This was a response to keep up with the growing population (Giri 1997). Due to the lack of new land suited for agriculture, an intensification of the already cultivated fields was needed. Agricultural intensification might be defined as “*increased average inputs of labour or capital on a smallholding, on cultivated land alone, or on cultivated and grazing land, for the purpose of increasing the value output per hectare*” (Tiffen et al. 1994:29) The new cultivars was not only better yielding and more tolerant to diseases and insects, they had a shorter growing period as well. This made it sometimes possible to squeeze one more crop into the annual rotation cycle (Timsina and Connor 2001). The result is often claimed to be depleted soil fertility, due to limited input (Giri 1997).

The introduction of high yielding cultivars and increasing use of nitrogen and phosphorus is often called or related to “the Green Revolution”. This led to an indisputable growth in agriculture all over the world. Andersen (2002; 2006) suggests, however, that micronutrient density in grains is likely to have become reduced as a result of these changes. This is problematic especially for the poorest people, who almost eat nothing but white rice. He therefore connects the phrase “empty calories” to the “the Green Revolution”.

3.3.6. High Value Cash Crops.

One way of intensifying agriculture is changing from growing grain to growing high value crops (HVC). HVCs may be defined as market orientated crops with relatively high value and low volume (Kawamura 2001). Such crops often requests low space, but large inputs of labour and fertilizers. Examples of HVCs are basically vegetables and to some extent fruits. The obvious reason for subsistence farmers to grow such plants would be to sell them and generate income. This is especially a trend near the urban areas, where market connections are good (Carson 1992). Eating the HVCs themselves would generally not be cost-efficient compared to growing and eating grain. However, there are certain problems regarding growing and selling HVC for the average Nepalese subsistence peasant. As mentioned earlier, road connections are scarce and not well developed in the hills of Nepal. This may lead to the problem of getting the goods to the market. Indeed, the existence of a market is essential, if there should be a point in growing cash crops (Kawamura 2001). Potential buyers are typically restaurants as well as the growing middle class.

Knowledge is another issue. New crops often require new knowledge if high yields are to be obtained. HVCs will also generally require higher inputs of fertilizers and labour. In spite of these things, it seems like the cultivation of cash crops are increasing in all of Nepal, but especially near to large cities (Kawamura 2001). According to data from the World Bank (2005), the amount of fresh vegetables produced in Nepal has gone from 90,000 tons in 1961, to 1,715,000 tons in 2004.

This cultivation of HVCs might fit into the “the crop theory” of Von Thünen. It states that farmers choose different crops depending on the distance from nearest market. It is only valid if the farmer is interested in getting some of his crop/product sold at the nearest market, though. Von Thünen made four different zones surrounding the market. According to this

theory, one of the key attributes of a crop is the weight/value relationship. This is important because of the cost of transportation to the market. Thus, crops with high weight in proportion to value should be grown close to the market, as it would be expensive to transport it over great distances. On the contrary, expensive, low-weight crops may be grown farer off as well as close to the market. HVCs fit the latter description quite well, compared to a lot of other crops. This should mean that it can be cost-effective to grow them in more or less peripheral areas, without the best communications. Still, a minimum of transportation possibilities to the market is obviously required if one is to sell cash crops. In the case of HVCs, durability of the goods is just as important as transportation cost. Due to the relatively short best-before date of perishables, short transportation distances are favourable.

G.S. Paudel (2002) did a study in the Pokhara district showing that cultivation of fruits and vegetables is and has increased the last years. He claims that this is done because of shrinking landholding sizes, a growing population and a scarcity of non-farming employment opportunities.

3.4. HUMAN NUTRIENT DEFICIENCIES

As reviewed earlier, it is stated that soil micronutrient deficiencies are likely to limit yields. this chapter will briefly connect soil micronutrient deficiencies with human nutrient deficiencies in Nepal.

According to Bouis et al. (1999), 2.1 billion people globally are iron-deficient. Although anaemia and iron deficiency is well known to occur in the industrialized world, the problem is indisputably biggest in the poorer countries. Welch and Graham (1999) point out Asia to be specially exposed. Zinc deficiency in humans is suggested to be as important as iron deficiency, but the symptoms are more complicated and statistics therefore scarce. Focus has been directed towards “the green revolution” when these issues are raised. The noble goal of creating an agricultural revolution which produces enough calories for everybody might have backfired into nutrient deficiency problems (Welch and Graham 1999). The replacement of traditional varieties with new, high yielding varieties has been mentioned, but replacement of different crops has also taken place. As the new varieties of grain were introduced, growing plants like pulses have become less exciting for the peasants (Welch and Graham 1999). Figure 10 shows the dramatic change in production in South Asia from 1965 to 1995. Wheat production has increased with by 500%, while pulse production “only” has increased approximately 80%. This might seem as an overall high raise in food production, but as the population growth rate in this part of the world is very high, the amount of pulses per person is likely to have decreased. Andersen

(2003) suggests that pulses might be the “poor mans best source of proteins, zinc and especially iron”. The overall best source is red meat and animal proteins, but the average Nepali peasant can not afford

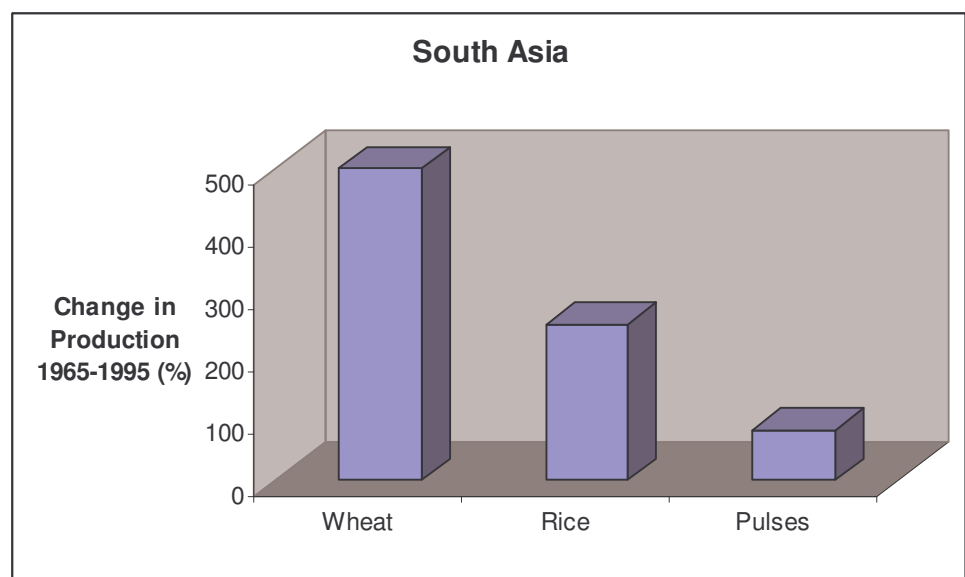


Figure 10: Data showing change in agricultural production in South Asia from 1965 to 1995. (From Welch and Graham 1999)

such an expensive diet regularly. The “worst” diet regarding these nutrients is white rice. The traditional national dish is called dal bhat and consists of rice and pulses. Andersen (2002; 2003) indicates that the reduction of pulses being cultivated could lead to increased iron and perhaps zinc deficiency in Nepalese people.

3.5. THE ECONOMIC BEHAVIOUR OF SEMI-SUBSISTENCE PEASANTS

According to the World Bank (2005), 22 93% of the workforce in Nepal are employed in agriculture. Of these, some 85% are involved in subsistence farming. Subsistence peasants do not follow the same logic “rules” as commercial peasants. First of all, they grow food to feed their own family. The part of their crop which they sell for income is not substantial. Input is therefore generally limited to what they can obtain on the farm. Chemical fertilizer inputs are usually small, basically because they do not have capital to buy it. Dependent on the degree of involvement with the market, semi-subsistence peasants might be a better description of the ordinary Nepali peasant (Grigg 1995).

As their main focus is to feed their family, a mixture of plants is preferable and characteristic. This makes the diet broader and reduces risks of entire crops failing. Since low yields might lead to starvation, risk minimizing is important. Labour is the main input and therefore is focus rather on maximizing gross production than profit maximizing. Output per hectare of land is also more important than output per head. The opposite is the typical focus of a commercial farm.

Put in a geographical view, one might say that subsistence peasants are largely dependent upon vertical connections. Vertical connections can be defined as the dependence of local natural sources (Holt-Jensen 1999). The agricultural inputs are obtained and the agricultural outputs are consumed at the farm. Peasants that are more involved in the cash economy are more dependent on horizontal connections. They may buy fertilizers, hire labour and sell their crops for cash elsewhere.

3.6. KNOWLEDGE

It is usual to differ between local and scientific knowledge. *“Local knowledge includes the complex of practices and decisions made by local people. It is based on experience passed from on generation to the next, but nevertheless, it changes, adapts and assimilates new ideas”* (Oudwater and Martin 2003). Andersen (2001) shows in his survey from Koshi Hills that hill peasants have little, if any, knowledge about nutrient problems from a scientific point of view. The status of the soil is explained through a “power” or “heat” concept (Andersen 2005). Although the peasants may not have knowledge of the nutrient issues, they may have means to correct the problem, such as draining a flooded field when the plants show signs of unhealthiest. As mentioned earlier, flooding is likely to cause nutrients to become unavailable.

A big issue regarding lacking knowledge of micronutrients is soil testing. The standard soil test covers macronutrients. A test of micronutrients is also available, but as peasants do not know what it is, they are not likely to ask for it (Andersen 2001). It seems clear that intensive agriculture is in need of scientific knowledge when it comes to inputs. The phrase “vitamin” may be a good indicator of “imperfect” local knowledge. “Vitamin” is a common local name for different fertilizers and growth conditioners available at the Nepalese market, which is applied more or less at random.

3.6.1. Extension service

“The past 40 years has observed several experimentations and the adoption of a number of extension approaches, but concrete achievements remain as elusive as ever.”

(Blaikie and Sadeque 2000;115)

The latter section illustrates a lack of connection between the scientific arena and the peasants. According to FAO/IFA (1999), the extension service provides a vital link between research institutions and peasants, and this is believed to be the most cost-efficient way of distributing recommendations. Carson (1992) urges that the extension system is there for the

peasant, and that the peasant should feel right to demand service from the extension officers. He also points out the importance of extension service in terms of risk minimizing.

The recommended ratio of peasants per extension officer is some 500:1 in an area like the Himalayas, where soil conditions may differ greatly within a small area. In a homogenous plain area, the ratio can be lower, because the extension officers can issue more general advises (FAO/IFA 1999). In reality, there are many more extension officers per peasants in the plains of Nepal, than in the hills (Andersen 2003). Studies made by Andersen (2001, 2002) shows that hill peasants contact with the extension service vary greatly, but is generally defective. The extension officers who do exist are accused of being unmotivated, as well as lacking a clear understanding of the agricultural system and not having knowledge of the relevant technologies (Carson 1992). The apprehension of the Nepalese extension service as largely malfunctioning is backed by Blaikie and Sadeque (2000). They argue that a more relevant and responsive extension service with an increased role for subject-matter specialists, along with a more interdisciplinary approach involving extensionists, research scientists and farmers should be present.

There are a couple of institutions that should be offering extension services in Nepal. MoA (Ministry of Agriculture) have a network of officers and does also produce a radio programme aimed to help peasants. NARC (Nepal Agricultural Research Council) does the research and issues the recommendations to MoA. Criticism has been made against NARC, though. The system is said to be too state-centric and have a technocratic attitude to the development of recommendations to peasants (Andersen 2003). Some NGOs might also be able to support peasants in soil testing and extension advises. AIC and private fertilizer distributors are distributing some knowledge as well. Still, the private traders operate after the simple logic of supply and demand. If there is no market for micronutrient fertilizers, they will not import any. And without knowledge, there will be no market (Andersen 2001; 2002).

3.6.2. Blanket recommendations.

Obviously, tailor made recommendations based on intensive soil testing for each single peasant is preferable, if he is to get the most out of his land. As we have seen however, the situation regarding extension and recommendation service is far from ideal in the hills of Nepal. Combining that with the high complexity of the Himalayan soils, it is logically to think that blanket recommendations might be too general and not suited for this area. However, this has never been proven, according to Andersen (2003; 2005). He believes that especially boron recommendations could be profitable as there seem to be a general boron deficiency almost everywhere. He also claims that blanket recommendations of zinc are more problematic, as zinc seems to be more or less dependent upon geology. This leads to high levels of soil zinc in some places.

There are two main problems with blanket recommendations. The first, and most obvious one, is that the various nutrient levels will probably cause some farmers to apply recommended fertilizers to soils already containing sufficient nutrient levels (Andersen 2003). When this happens, it is very likely that the increase in yields does not match the expenses of buying fertilizers. This leads to the question if it is ethically correct to try to help the greater amount of the peasants, when you know that some of them might actually suffer from your actions. The other main problem associated with blanket recommendations is the risk of toxication. If there are high values of nutrients and you add additional amounts of for instance zinc, you might have a problem. This is normally not considered a big problem as very high zinc values are seldom found in these soils (Andersen 2002). The difference between boron deficiency and toxicity is quite narrow. Therefore, boron toxicities might be an issue regarding blanket recommendations.

If one is to say that there is an existing recommendation for the hills of Nepal, it is to apply chemical fertilizers in the shape of urea and DAP. As mentioned earlier, there was an unpublished project by FINNIDA where they tested blanket recommendations of two micronutrient blended fertilizers in the area around Kathmandu. This project was said to be a success. Andersen (2003) suggests that it might be a good idea to introduce micronutrient blended fertilizers connected with blanket recommendations once again.

4. METHODOLOGY

The main approach used in this study is what one might call a farming system approach. Farming system factors, such as fertilizers, are used to investigate the available boron- and zinc levels found. These data have been gathered by interviewing peasants. Soil samples were taken at the same time.

In this chapter we will have a brief look at some of the issues connected to working in an unfamiliar culture, the use of deductive and inductive methods as well as how I have gathered data.

4.1. WORKING IN AN UNFAMILIAR CULTURE

There are several aspects of working somewhere far from home and in an environment you do not know. Questions that might seem logic to the researcher can be misunderstood by the informant. Likewise, answers from the informant can be misinterpreted by the researcher, as knowledge bases differ from culture to culture and society to society. A common problem is that the informant leaves out an important point because she or he thinks that it goes without saying. Also, status of the researcher can determine what answers the informants are giving.

4.1.1. Status

When I first came to Pokhara, I was perceived as a tourist by the locals. The city attracts a lot of trekkers, so Europeans are a trivial sight there. This made it easy getting around without interference of any kind. The tourist status seemed to stick, however. When I started doing fieldwork a lot of people asked me why I would have any interest in taking soil from random fields and asking silly questions. They obviously could not fit this to the tourist role. Still, many of them thought of me as a tourist. This did not cause me any problems, as I was allowed to ask questions and take soil samples anyway. It was not until later people actually started looking at me as some kind of a scientist. The word had spread around the village and the general opinion had changed. The way I experienced this was that people started asking me for advices regarding fertilizers use and rotation of crops. Still, at the very end I think

some people, especially the older ones, did not accept me fully for doing scientific work. This is obviously connected with the fact that I presented myself as a student, but I think my age also played a part. Being twenty-three probably made the scientist role hard to fit. As everybody knows, wisdom is connected to age.

The status of a white researcher/student certainly opened some doors. I could get away with asking stupid questions and people were generally extremely open and welcoming. The fact that somebody from far away was asking the questions probably made it more legitimate. The people of Nepal was experiencing some hard times as the Maoist insurgency still was on when I did the fieldwork. According to most people, both the King and the Maoists had spies everywhere. Talking to unfamiliar Nepalese about anything but strictly trivial things is therefore connected to great risk. I found this odd as micronutrients and agriculture do not seem to be connected with politics. As far as I know, my interview guide did not touch any sensitive subjects. Still, my field assistant thought that she would have trouble carrying out the study alone. With the presence of a European researcher/student, however, the informants knew that the enquiry had no involvement with the government or the Maoists.

4.1.2. Operating in an unknown area

Obviously I had read as much as I could about Nepalese agriculture before I went to do my fieldwork. Still, my knowledge about the area was limited. In fact, the final election of study area was not done before reaching Pokhara. As a result, I knew very little about the land owning system. Actually, some of the fields in my study area were owned by people living in the centre of Pokhara, in Kathmandu and at a high ridge above Phewa Tal. In a couple of those cases I met the people who took care of the land for the owners. This was sufficient, as they could answer my questions. It was frustrating when I did not find the owner or the caretaker, though. It reduced the fields I could choose from within my study area.

My biggest help in getting to know the study area was of course my field assistant. Although she was from Kathmandu, she connected well with the locals and found out what I needed to know. At our first day we ran into a man who showed us around and answered a lot of questions. If I can say that I had any, this man became my key informant. I also introduced me to the chief of the village, who allowed me to gather data in Sedi Bagar. Without my assistant

and this key informant, I probably would have made a fool out of myself, going around asking questions without approval from the chief.

Doing fieldwork in an unknown area and culture is hard because you have to try to be open to new ideas and possibilities, and at the same time be careful not to step over the boundaries which the culture puts on you as a researcher.

4.1.3. Case study

Case studies are defined by Stake (2000) as a form of research interested in individual cases. This definition occur a bit vague before we discuss what an individual case is. In humanistic science, it is logical that it is the individual itself. In my study it is not that straightforward. Is it one single peasant or can an individual case be the farming system in a single village? I choose to put my faith in the latter example.

Case studies are often connected to qualitative research, due to the in-depth study method. Usually, a limited number of samples are investigated and the area of the study is severely restricted. My study is primarily a quantitative one. Still, I think of it as a case. This is basically due to the limited area, as well as the fact that I am not really trying to make any general statements.

Stake (2000) divides case studies into two major categories. *Intrinsic* case studies are undertaken when the researcher wants a better understanding of the particular case. *Instrumental* case studies, one the other hand, are done to facilitate an understanding of something else. The obvious example is when a case study is used for generalization.

I consider my case study to be of an intrinsic character. The most important is the case itself, and although using it to generalize would be nice, I do not think it is possible to accomplish this with the necessary reliability. This is due to the fact that my study area can not be regarded for certain as a “typical” Nepalese farming area with “average” soil conditions and a “general” farming system. Comparing with similar case studies is of course possible.

The major advantage of doing a case study is that you are likely to obtain a source of ideas regarding the causal connections between the variables in the study (Hellevik 1999). “*Why* is it exactly like this, exactly *here*?” is therefore a useful question to ask. The main goal for my

work is to find some explanations to the distributions of available zinc and boron values. The idea is that a case study can reveal more than a study of greater geographical extent.

4.2. DATA COLLECTION

The data collection was carried out in May-June 2005. I have two forms of data; interviews and soil samples.

For each soil sample, the owner of the field was asked to answer ten quite straightforward questions regarding the field which the sample was collected from. The questions were the same for all informants. This interview form or guide (Appendix I), must be seen as quite rigid and quantitative. Still, I gave myself room to ask supplying questions, when I found it interesting or necessary. Having a rigid interview structure is suitable if you are to limit the use of time on each informant. Another advantage is that the data is more easily comparable than if I was to have a more flexible approach. This is obviously important, as I am using the data statistically. Because of this, all answers to my questions can easily be categorized.

The soil samples were collected at random fields within the study area (Sampling pattern will be discussed in chapter 4.3.3.). For each composite sample, I took five sub samples from different parts of the terrace at some 20 centimetres below the soil surface. The distance between each sub sample was at least a couple meters. These were mixed and strained before being put into polyethylene bags, some 150 grams of soil each. The nutrient and pH extraction was done by the following procedures at Nepal Environmental and Scientific Services (NESS):

Available Zinc: The available zinc of the air dried and sieved soil sample was extracted with DTPA micronutrient extraction method. Twenty gram of the 2mm sieved sample was weighted and taken into a 100 ml capacity PVC bottle. The extracting solution was prepared by dissolving Trietanolamine, Diethylenetriaminopentacetic acid (DTPA) and Calcium Chloride in water whose pH was maintained at 7.3. Temperature of the extracting solution was measured before adding to the soil sample. Then 40 cc of this extracting solution was added to the sample and stoppered well. It was placed horizontally on the reciprocating shaker

and shaken for two hours. After two hours shaking the extract was filtered through medium textured filter paper and the determination of the available zinc was made in the extract by AAS.

Water Extractable Boron: Twenty gram of air dried and sieved soil sample was taken in 125 ml boiling flask and forty millilitres of distilled water was added to it. The flask was fitted with condenser and heated to boil for five minutes. It was allowed to cool and 2-4 drops of 1N calcium chloride solution was added to it and centrifuged for 5-10 minutes and then filtered to get the clear extract. The last step of the extraction process was not included in the lab report, but usually the extract is measured by a spectrophotometer. The extract can also be compared to standardized solutions visually. The latter method is obviously not as accurate as the one with the spectrophotometer.

pH: Twenty gram of the air dried and sieved (2 mm) soil sample was taken in a 50 ml beaker and 20 ml of distilled water was added to it. It was then shaken well for one minute in mechanical shaker. The mixture was let to be settled for about one hour.

NESS is known as one of the most trustworthy and reliable labs in Nepal. I therefore reckoned my samples to be in good hands. To be completely sure of this one might argue that control samples should have been obtained and analyzed. Also, getting results from different labs would be preferable to secure reliability. We do not live in an optimal world, though, and my resources were inadequate to carry out extensive sample testing.

Testing soil for available boron is not completely standardized (Gupta 1993). This induces problems when it comes to hot water extraction of boron. As mentioned in chapter 4.3., it seems like NESS cooled the hot water extract before filtering (various information has emerged from NESS). This causes underestimation. Jeffrey and McCallum (1988) tested the effect of cooling the solution before filtering and found between 15 and 33% higher boron concentrations with hot water filtration than with cold. The average percentage was estimated to be 25. Thus, if the “normal” procedure had been followed and the water had not been cooled before filtering, my samples would generally have 25% higher boron values. This is due to some boron getting attached to the soil particles when the water cools (Jeffrey and McCallum 1988). The soil boron figures demonstrated in this thesis have been adjusted

according to a 25% underestimation. As 25% is an estimated average, the reliability of the new values is very much a subject to uncertainty.

Boiling time before boron extraction is also somewhat disputed. Gupta (1993) claims that five minutes may not be sufficient, while Jeffrey and McCallum (1988) argues that there is no difference between boiling the sample for five, ten or fifteen minutes. NESS boiled my samples for five minutes and I reckon this as adequate.

Standards and methods vary, so NESS has technically not done any mistakes with my samples (that I know of). The main problem is related to lacking standards for hot water extraction of soil boron. This experience demonstrates that one should be critical to the analysis made by labs.

4.2.1. Quantitative and qualitative data.

This section will briefly explain the difference between qualitative and quantitative data and why I have chosen to utilize the latter type most.

Quantitative and qualitative data are obtained in different manners. The interview is often connected to the gathering of qualitative data. The main direction of the conversation is pointed out at the start, but the structure is fairly loose. It is expected that there might come up new and surprising data to the researcher. The obvious strength of the qualitative approach is the flexibility. It allows the researcher to go further into subjects he might find interesting and get more data on certain areas than a quantitative approach usually would do. As quantitative research often is bound to a question form, the researcher has fewer options to alter the course of her research during fieldwork. This is because he usually needs to ask the same questions to his informants. Quantitative studies are therefore often very structured and rigid. The advantage is that the researcher will get compatible data. They are also more efficient if one is to collect a lot of data in a limited period of time and have a bigger number of informants (Hellevik 1999). Some argue that qualitative work should be more or less explanatory, while quantitative work should try testing hypotheses. I do not think that it necessarily has to be this way, but what seems clear is that quantitative approaches generally not are suited unless the

data is well defined. Holt-Jensen (1999) claims that both qualitative and quantitative methods often are fruitful when doing research, and I very much share this view.

Qualitative and quantitative data is connected to the intensity of the research. An extensive approach is when you have many informants, but few variables. If there are a limited number of informants, but lots of variables, the method should be called intensive. Intensive on the informants, one might say. Basically, extensive research is often incorporated in quantitative work, while qualitative research is often intensive. As mentioned, the biggest difference is the depth versus width of the data (Hellevik 1999).

My study is mainly quantitative and extensive as I have many informants, but few variables and most of my data are in numbers and strict categories. The only qualitative data are some supplying questions to the peasants and conversations with the people at the local Agro-vets. The main advantage of doing it like this is that I can use almost all my data statistically and in a GIS. Also, I was able to do a research with relatively many samples without using too much money and time.

4.2.2. Validity and reliability.

Validity and reliability are important conceptions in research. Following is a short review of the two, as well as a few examples on how my work may be subject to low validity and reliability. This subject will be more thoroughly examined when discussing my hypothesis in chapter 6.1.

A well know expression is the validity of research. Having good validity implies that what you measure is the same as what you should measure. Put in other word, that what you measure is relevant to your hypotheses. As Hellevik (1999) points; it is no good having a lot of nice data if it can not throw light on your hypotheses. The problem seems often to be the distance between empiricism and theory. When you have a theory, you can not always test it directly. For instance, I have a hypothesis regarding intensification of the Nepalese agriculture. This is hard to measure directly, as intensification is made of several factors. In addition, the very definition of intensification is discussable and people may have different interpretations of it. Trying to test the mentioned hypothesis by just asking the peasants if they

have intensified their farming system, would therefore probably not be very smart. The result might be that the peasants interpret the question in different ways. This is often referred to as low validity of definitions. Because of this problem, I investigated factors known to lead to intensification of agriculture. By doing this, I hoped to keep a good validity.

I think my interview guide (Appendix I) is quite straightforward and hard to “misinterpret”. A big help to me was my field assistant, who was from Nepal and had a lot of knowledge regarding Nepalese farming systems. By discussing the different words and terms in the interview guide with her, I was able to see what might become problematic. The most important thing was to agree upon the level of details we should ask for, so that the data was comparable. “in-situ green manure” was a term that needed a bit more elaboration. The definition I ended up with was “Green organic parts of plants incorporated into the field to raise fertility, which had not been in contact with manure or been composed”.

Reliability is also an important expression connected to gathering of data. One might say that the reliability of data says something about the accuracy of the data collection. For instance, if I have been doing sloppy soil sampling or not been accurate with my registration of coordinates, this would lead to low reliability of my data. A test can be done by doing the same test twice at the same locations. If the results are the same, it means that the reliability is likely to be good. Regarding the soil samples, chemical extraction of boron and zinc obviously seems to be a very reliable measurement of available boron and zinc. As argued in part 3.1.3., however, the available amounts of the micronutrients are dependent upon a range of soil factors. As my resources are limited, I have not been able to extract these soil factors and therefore can not say if the zinc and boron levels of my data should be corrected. This fact weakens the reliability of my data. The initial plan was to extract the relevant soil factors, but due to lack of funds this was not done.

4.2.3. Sampling pattern.

Once I had chosen study area, the next thing was to decide where to pick each sample. I had pictured the situation in my mind before I left for Nepal, and thought that a grid selection would be best. This seemed like the most structured and methodical way of doing it. I would be able to cover the whole study area and the data would be very suitable for interpolation.

Unfortunately, you are often forced to change your plans during field work, and in this case I had to do exactly that. Looking back at my planning, I realize that I did not take infrastructure, informants, topology and landscape into account. I more or less pictured a homogenous area and informants that were always home and available for interview. Obviously, this did not fit to reality. The size of the fields differed a lot and therefore made it hard to make a good grid.

The biggest problem, however, was the availability of people. From time to time, the houses I approached were empty and I had therefore little choice but to walk on to the next house. Starting the fieldwork earlier each day helped as I met people before they left the house, but still I forfeited the attempt to make a perfect grid of my samples. What I ended up with was what one might call a random sampling method. As my sample map (figure 11) illustrates, the distribution is very uneven, with some clusters in the centre of the study area. One problem was that the peasants owned land patches far from each other. Usually each housing had some bari close to the house and a patch of khet quite far from the house. Thus, when I approached a house and asked to take a sample from their khet and bari, I had no control of where the samples would be taken. This resulted in a far bigger study area than I first intended. When I gave up the grid selection I altered my method to a random selection. However, the more I reflect on this, the less random it seems. I went from house to house, trying to find the peasants. At the time, it did not occur to me that this selection might not be representative for all the farmers and all the fields in the area. Some might be part-time farmers, working other places. Others might simply have different working routines and not be at the house when I was there. I do not think that this was a huge problem though, as I found people in most of the houses I visited.

What might have been a bigger case was that a vast amount of the land, especially khet, was owned by people outside the village. I did not become aware of this fact before the very end of the fieldwork period. Then I was told that some people from the ridges around Phewa Tal as well as people from Pokhara and Kathmandu owned patches of land in the area. This happened as I was about to finish working, so I was not be able to contact any land owners in Kathmandu or Pokhara. I did walk up to a ridge some 500 meter above Phewa Tal to interview some peasants however. The random selection offered me more problems as my picking of houses probably was not random. I walked along roads and tracks, and therefore probably made some sort selection. It is likely that I subconsciously picked the houses at the

most convenient locations. This is called roadside bias and means that I do not have fully representative data of the area.

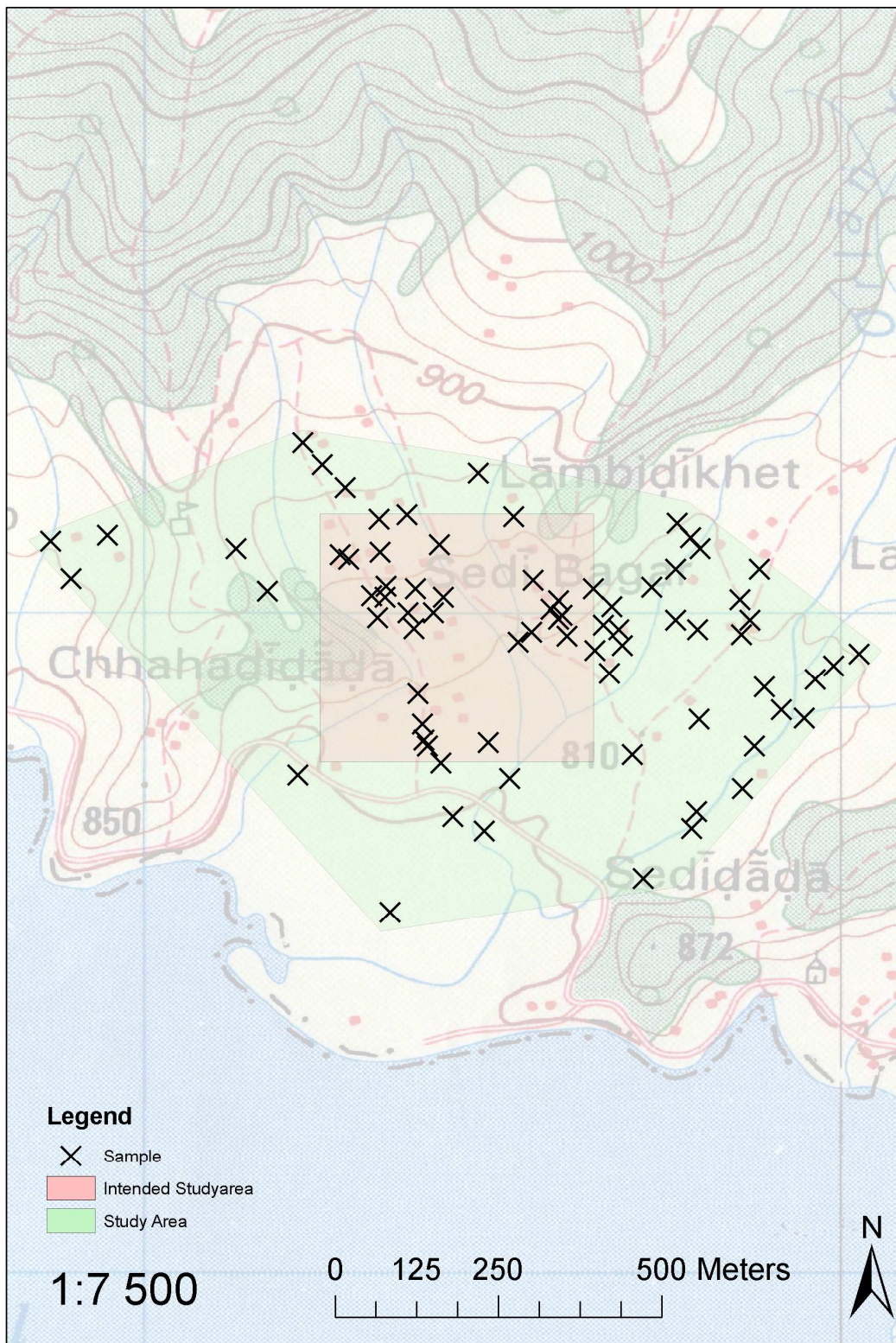


Figure 11: Map of sampling pattern.

4.2.4. Soil sampling methods.

For each composite soil sample, I took five sub-samples. After finishing my fieldwork, I still think that this was sufficient, but one might argue that I should have taken more sub samples. The background for this criticism is that one of the sub-samples might have hit a cowpat or another sort of matter with unusual boron or zinc values. Blending together more sub-samples would usually normalize this.

My objective was to take the samples from 20 centimetres depth. Doing this in khet- and vegetable fields was usually not a problem. In the bari, however, the quantity of stone made it hard to get the drill to the sufficient depth. As a result, some samples were taken slightly higher in the soil than at 20 centimetres depth. This is problematic as nutrient levels differ with soil depth.

4.2.5. Interview guide.

One might say that the interview guide (Appendix I) is too rigid. As a result, it is possible that I missed valuable data. The obvious weakness of using an interview guide like this is that it reduces the chance of finding unexpected data dramatically. Still, I thought that getting statistically comparable data was the most important thing.

The questions in the interview guide can be subject to some criticism. Some of them are not as interesting as I had hoped when I designed them. For instance, question nine might seem a bit pointless when looking at my data. The purpose was to find type and amount of applied green manure. What I did not know was that no one in my study area used green manure. All the interview guides were therefore blank on question nine. One might say that this is a good finding, but I think that I could have revealed this by doing better pre-research. In this way I could have used the time to ask a more fruitful question.

One such question I would have liked to add was whether the peasants were satisfied with the fertilizer recommendations they got. Although I got the impression that they were not, it would have been nice to quantify this. I suppose not being perfectly happy with the data gathering comes part in part with any study, especially when you do it in an unknown culture and an unknown area.

4.2.6. Using a translator.

Although I was very satisfied with my translator, there are some problems connected to using such translators in general.

Implicit knowledge is one such issue. The informant and the translator often share information which is unknown to the researcher. This information may not be mentioned as the translator recons it as a universal fact. In this way valuable data might be lost or the researcher gets an incomplete impression of the picture. It is hard to say if this was the case with me, but the possibility should not be left out. However, I think that discussing the fieldwork and my assumptions with the translator prior to the interviewing was a smart thing to do. In this way, I got to tell her what I knew about Nepalese agriculture, and more importantly, what I did not know. I was very fortunate as my translator happened to have a bachelor degree in forestry. As forest and agriculture is very closely related, she also knew a lot about the topic of the research.

When interpreting through a translator, the answer goes through two segments. This obviously weakens the validity of definitions, mentioned in chapter 4.3.2. Conceptions differ, and a term such as green manure may be subject to this. This can possibly be one of the reasons to why I got the same answer from all informants regarding use of green manure. The solution is of course to have good definitions.

Another known problem with translators is that they may answer the questions themselves. I absolutely do not think this was the case for me, but it should be mentioned. Especially if the translator feels more qualified to answer then the informant, this might be the case. Off course, this ruins the whole idea of interviewing different persons, but it might not be as logical to the translator as it is to the researcher. I had a translator who had done somewhat similar studies her selves, so I assume that she knew the methodical drill of interviewing.

5. DATA PRESENTATION AND ANALYSIS

In this chapter I will present and analyse the data I have collected. The underlying goal is obviously to falsify my hypotheses, but that discussion will take place in the next chapter. My main tools are SPSS, which is a statistical program and a GIS package called ArcGIS 9. I will use SPSS to explore my data, as well as doing correlation analyses. ArcGIS will be used to carry out the spatial analyses.

Table 1: Statistical overview of continuous data

| | N | | Mean | Median | Std. Deviation | Range | Minimum | Maximum |
|----------------------------|-------|---------|------|--------|----------------|-------|---------|---------|
| | Valid | Missing | | | | | | |
| Kg DAP per ha | 73 | 0 | 33 | 16 | 45,7 | 200 | 0 | 200 |
| Kg Potassium per ha | 73 | 0 | ,7 | ,00 | 5,8 | 50 | 0 | 50 |
| Kg Urea per ha | 73 | 0 | 43,3 | 20 | 66,5 | 320 | 0 | 320 |
| Kg Poultry manure per ha | 73 | 0 | 92,4 | ,0 | 558,2 | 3750 | 0 | 3750 |
| Tons FYM per ha | 73 | 0 | 14,9 | 8,0 | 19,1 | 100 | 0 | 100 |
| Oxen | 73 | 0 | ,6 | ,0 | ,7 | 2 | 0 | 2 |
| Cows | 73 | 0 | ,3 | ,0 | ,9 | 7 | 0 | 7 |
| Buffaloes | 73 | 0 | 1,4 | 2,0 | 1,1 | 5 | 0 | 5 |
| Goats | 73 | 0 | 1,3 | ,0 | 1,8 | 6 | 0 | 6 |
| Size of sampled field (ha) | 73 | 0 | ,22 | ,15 | ,2 | ,94 | ,01 | ,95 |
| pH | 73 | 0 | 5,6 | 5,5 | ,75 | 2,9 | 4,5 | 7,4 |
| Boron ppm | 73 | 0 | ,92 | ,91 | ,54 | 2,0 | ,10 | 2,0 |
| Zinc ppm | 73 | 0 | 2,80 | 1,79 | 3,02 | 13,9 | ,10 | 13,9 |

5.1. EXPLORATORY DATA ANALYSIS

Pallant (2005) argues that it is important to explore your data. This gives you an overview of the data and helps you to decide which statistical methods to use later in the analysis. Exploratory data analysis is often called descriptive statistics. Of course, descriptive statistics can also be used to address specific research questions. One might argue that exploratory data analyses largely are of inductive character as data or trends in data that stand out of the crowd are likely to catch the interest of the researcher. Even so, “getting to know” the data is important and as discussed earlier am I not a fan of discarding the possibilities inductionism serves us.

My first task is to demonstrate the distribution of the data. Obviously, the boron and zinc values are most important.

Table 1 shows us some key figures about my continuous data. What immediately attract attention are the extreme variations of the fertilizer data. This is due to the fact that some of the peasants do not use all kinds of fertilizers.

Regarding the two micronutrients, we can see that zinc has a much bigger range and standard deviation than boron. Both have a minimum of 0. It does not necessarily mean zero, though. This is because the range between 0 and 0,1 ppm is below detectable levels to the tests applied. It is therefore impossible to know the exact value if it is somewhere below 0,1 ppm. I have set it to 0, because SPSS needs an exact figure.

The mean, variance and standard deviation tell us something about the distribution of data, but not enough. Worth noting is the high mean of zinc. If this mean is representative for all my zinc samples, a conclusion might be drawn saying that there are no zinc deficiency problems in this area. To investigate the distribution of micronutrient levels further, we will use a couple of other descriptive techniques.

A useful graphic that gives a good summary picture of the data set is the box plot (O'Sullivan and Unwin 2003). In a boxplot, the box itself is the inter-quartile range of the data and the line in the middle is the median. The whiskers of the plot extend to the highest and lowest value of the dataset, within 1.5 boxlengths of the upper and lower quartile. If any data values exceed the whiskers, they are regarded as outliers (Pallant 2005). These values are marked individually with their sample number next to them.

Figure 12 shows us that the distribution of zinc and boron values differs greatly. While the boron data is distributed between 0 and 1.6 ppm, the zinc values have a much more extreme

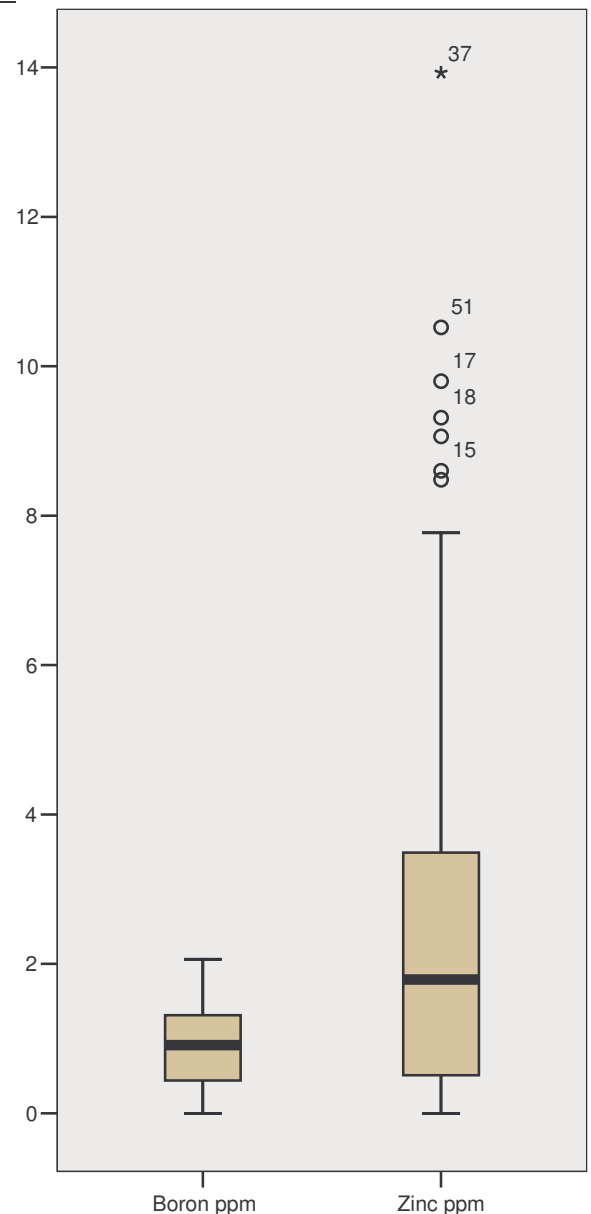


Figure 12: Boxplot of the boron and zinc distributions.

and varied pattern. As we can see from figure 12, the inter-quartile range of the boron data is fairly narrow. Obviously, this means that the boron values around the median are quite similar to the median. This impression is reinforced when you compare it to the inter-quartile range of zinc, which is much broader. What is really interesting with these boxplots is the amount of outliers. SPSS recognises no outliers in the boron boxplot, as there are no values exceeding 1.5 box-lengths from the edge of the box. In the case of zinc, on the other hand, we see several outliers. There is even an “extreme point” (Pallant 2005) represented by the maximum zinc value. As we could see in table 1, the mean zinc value is some 2.8 ppm. This is a high figure compared to the boron mean of 0.7 ppm. It seems evident that the zinc outliers are affecting the mean or even making the mean not representative for the whole data material. By doing a 5% trimmed mean calculation we can say something about how much the extremes are affecting the ordinary mean. To obtain this value, the statistical program removes the top and bottom 5% of the values and calculates a new mean. The boron mean did not change to a notable extent by this. The zinc mean went from 2.8 to 2.5. Bearing in mind that all the zinc outliers did not fit into the top 5%, it is probably safe to conclude that the outliers have a huge impact on the mean. This makes the mean unsuitable to describe the data material as a whole. The median of 1.8 strengthens this claim, but can the median itself be used as a sort of key figure for the data? The median is dependent on a sort of “normal” distribution to apply as representative. Pallant (2005) describes a normal “distribution” as a symmetrical, bell-shaped curve with most scores in the middle and fewer towards the extremes. Assessing “normality” can be done with a Q-Q plot (also called probability plot).

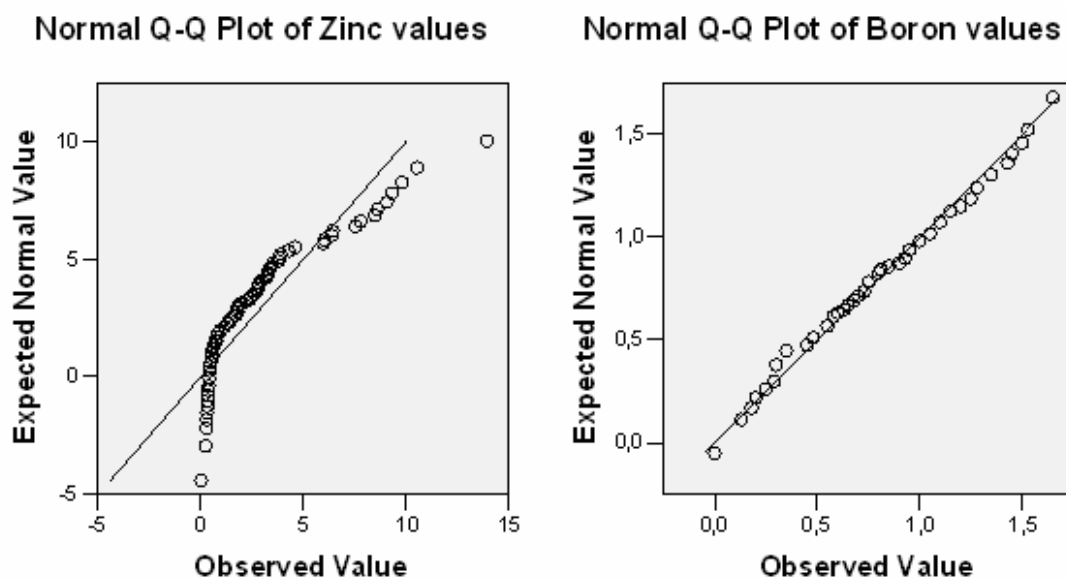


Figure 13: Q-Q plots of the boron and zinc data. Note that negative values for zinc are expected as the distribution is not normal.

In a Q-Q plot each value is plotted against the expected value from the normal distribution (Pallant 2005). If the data are normally distributed, the data values are supposed to follow a somewhat straight line, which is the case for boron. As we might have guessed, the zinc Q-Q plot does not follow the same pattern. What we can read from this figure is that there are most values at the very bottom of the range instead of highest frequency around the median. The relative high median and mean of available zinc is therefore not representative for the dataset as a whole. Something is going on which needs to be pinpointed. This will be investigated in a later section.

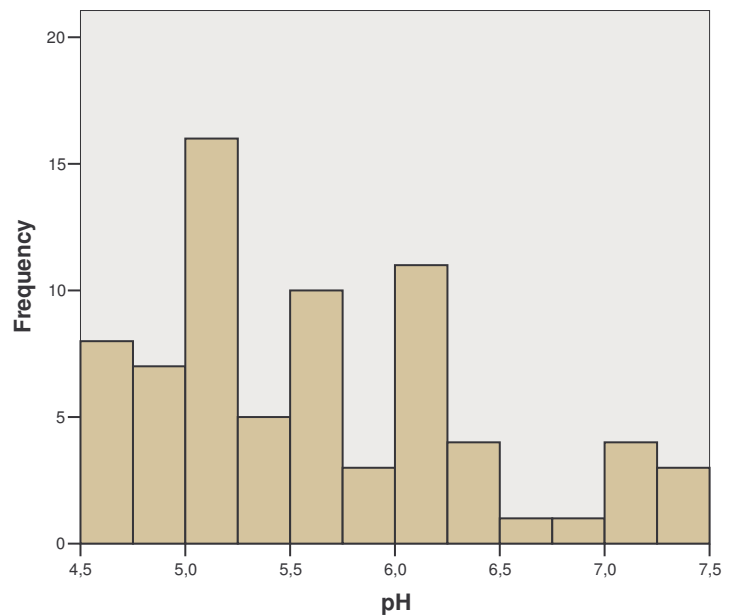


Figure 14: Bar graph of pH-values.

A histogram of the pH in the sampled fields (figure 14) shows us that there are more acid soils than alkaline. This corresponds well with the mean from table 1.

Regarding the fertilizer data, potassium and poultry will not be viewed here as only a couple of the peasants used this kind of input. By doing frequency tests of the other fertilizers, we see that zero is a key figure. Some 20 percent of the fields investigated have no added FYM. For DAP and urea, the rates are 37 and 30, respectively. Along with some high values, like the maximum FYM value of 100 tons per ha, this makes the standard deviations high.

Table 2 Statistical overview of categorical data.

| Land Category | | | Use of animal bedding | | |
|----------------------|-----------|---------|------------------------------|-----------|---------|
| | Frequency | Percent | | Frequency | Percent |
| Bari | 44 | 60 | Yes | 48 | 66 |
| Khet | 23 | 32 | No | 25 | 34 |
| Vegetable garden | 6 | 8 | Total | 73 | 100 |
| Total | 73 | 100 | | | |

| Present crop | | | Main animal food | | | |
|-----------------------------|-----------|---------|---------------------------|-----------|---------|-------------|
| | Frequency | Percent | | Frequency | Percent | Valid Perc. |
| Maize | 14 | 19 | Straw | 5 | 7 | 8 |
| Pasture | 20 | 27 | Straw / Green fodder | 54 | 74 | 89 |
| Maize / vegetables | 29 | 40 | Straw/Green fodder/ Grain | 2 | 3 | 3 |
| Rice | 2 | 3 | Total | 61 | 84 | 100 |
| Maize / vegetables / fruits | 2 | 3 | Missing | 12 | 16 | |
| Vegetables | 6 | 8 | | | | |
| Total | 73 | 100 | | | | |

The frequencies of my categorical data are summed up in table 2.

It is worth noting that 60 percent of the samples are taken in bari terraces. This was not intentionally, but a result of the accessibility of the peasants. As mentioned in a former chapter, much of the khet land is owned by people from outside the village.

The vegetable gardens are small pieces of land close to the house where especially intensive crops like vegetables are grown. The data in table 1 and table 2 will be analysed further in the following chapters.

This exploratory data analysis reveals large differences in fertilizing practices. It also shows that available zinc varies a lot. The available boron range seems more or less normally distributed.

5.2. EXTENT OF BORON AND ZINC DEFICIENCY IN SEDI BAGAR

When applying the 0,6 ppm deficiency limit to the boron and zinc data, we get almost similar results. 22 samples are zinc deficient and 24 samples are boron deficient. This gives a deficiency percentage of 29 for zinc and 32 for boron. The figures are considerable, but not extremely high, as deficiencies of broader extent have been reported frequently in Nepal. Especially a more pronounced boron deficiency would be expected, as several studies from Nepal demonstrate widespread boron deficiencies up to as much as 80-90 percent (Sippola & Lindstedt 1994; Andersen 2002). Still, only 35 samples were not deficient in either boron or zinc. This is less than 50 percent of the samples and implicate that micronutrient disorders are likely to be a big problem in Sedi Bagar.

Only six samples are both boron *and* zinc deficient. These samples are all taken from khet fields in the eastern part of the study area. To investigate the distribution of boron and zinc data further, a thorough spatial analysis is required.

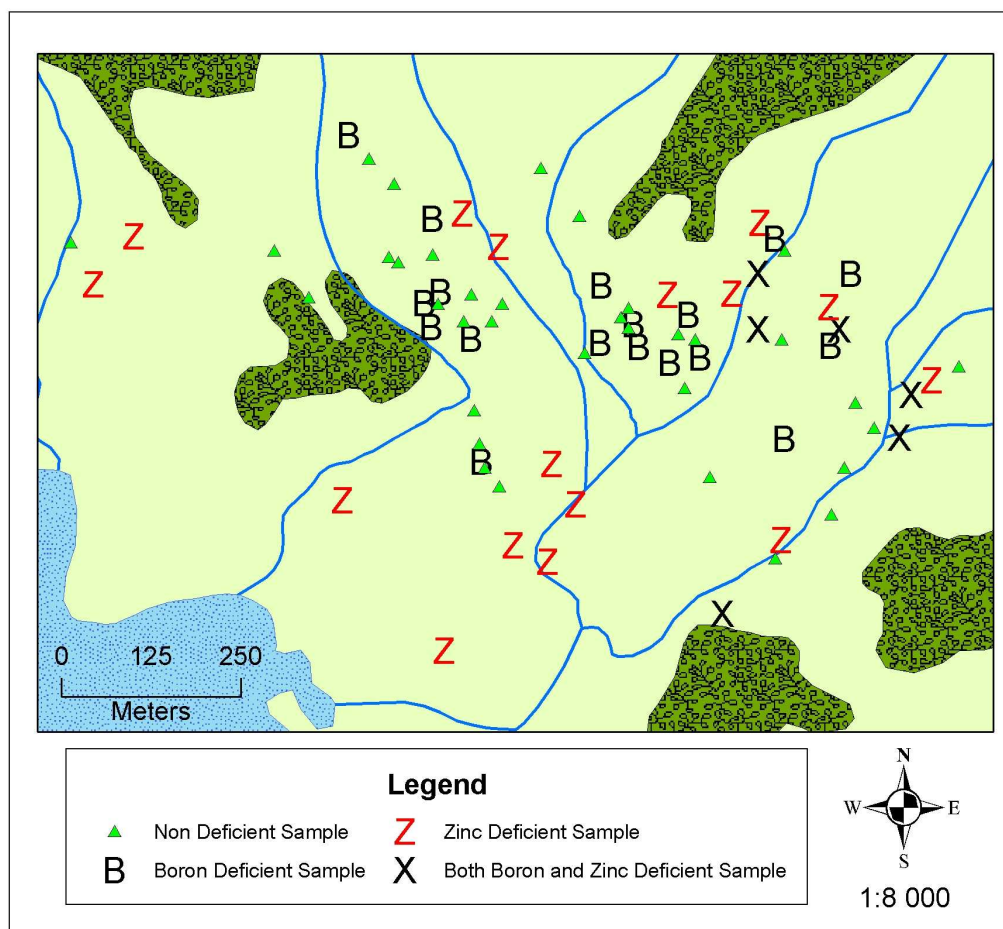


Figure 15: Map boron and zinc deficient samples.

5.3. SPATIAL DATA ANALYSIS

“Systematic information using GIS is very much needed for monitoring micronutrient deficiency in different cropping systems and soils/areas that so far remain uncovered..”

(Singh and Nayyar 2004; 21)

The following spatial analyses will try to reveal spatial trends and relationships. This is done to give a better understanding of the available zinc and boron distributions and perhaps the underlying causes.

5.3.1. A map overview of the zinc and boron data.

Figure 16 and 17 are overview maps showing the distribution of available boron and available zinc. It is hard to find visual patterns in the boron map as high and low values are very much mixed together everywhere.

It is easier to identify a pattern in figure 17. We see clearly that there are a lot of high values in the middle of the study area and mostly low values at the outskirts. The distribution of high and low zinc and boron values needs to be investigated further. We can also see that there is a pattern in the zinc distributions with regards to land categories. There are low values in both bari and khet, but almost no high values in khet. This needs to be examined further as well.

Note that the shape and size of the vegetable, khet and bari patches in figure 16 and 17 are not exact. They have been derived from proximity polygons used in chapter 5.3.2.

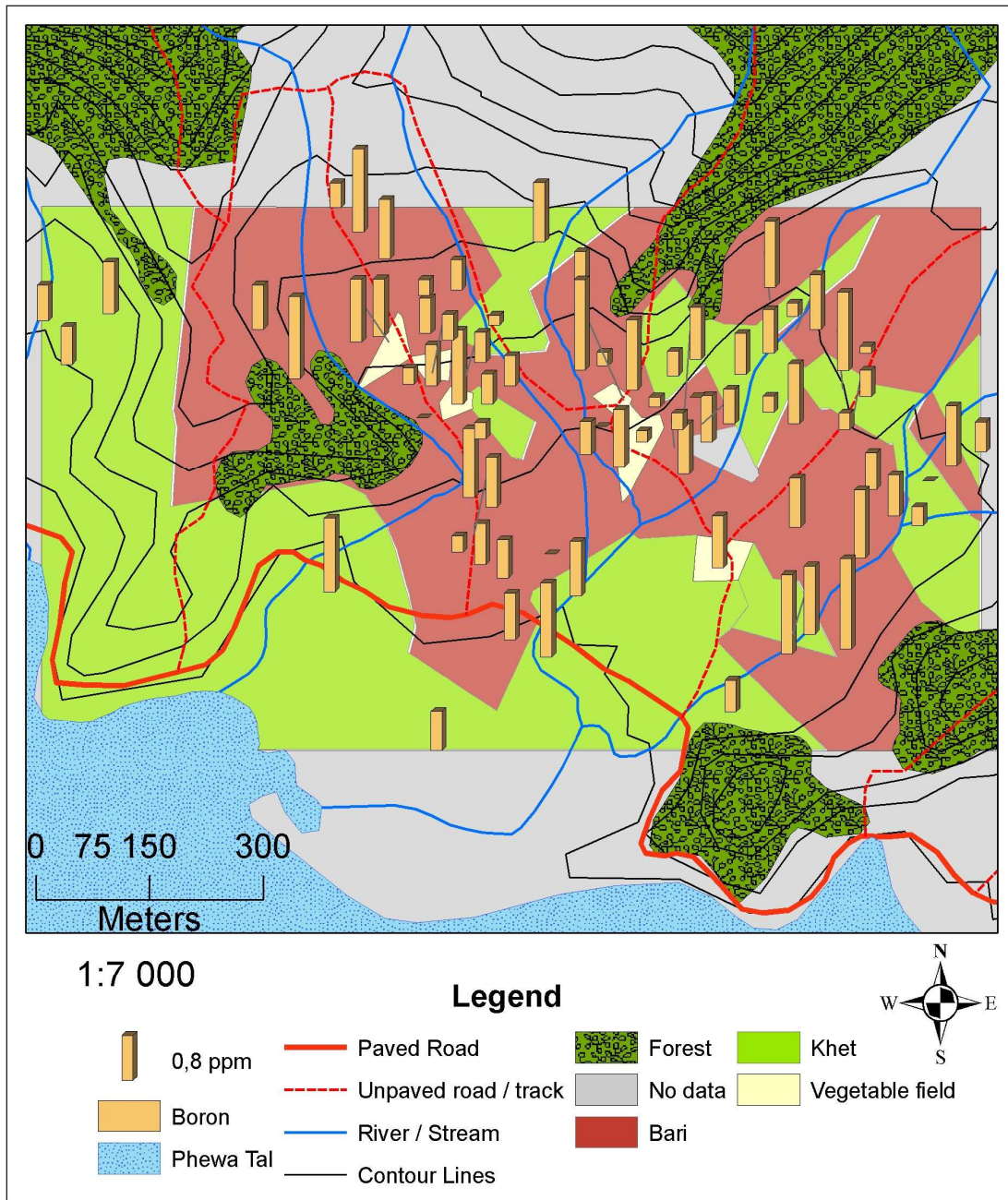


Figure 16: Map of the distributed boron values.

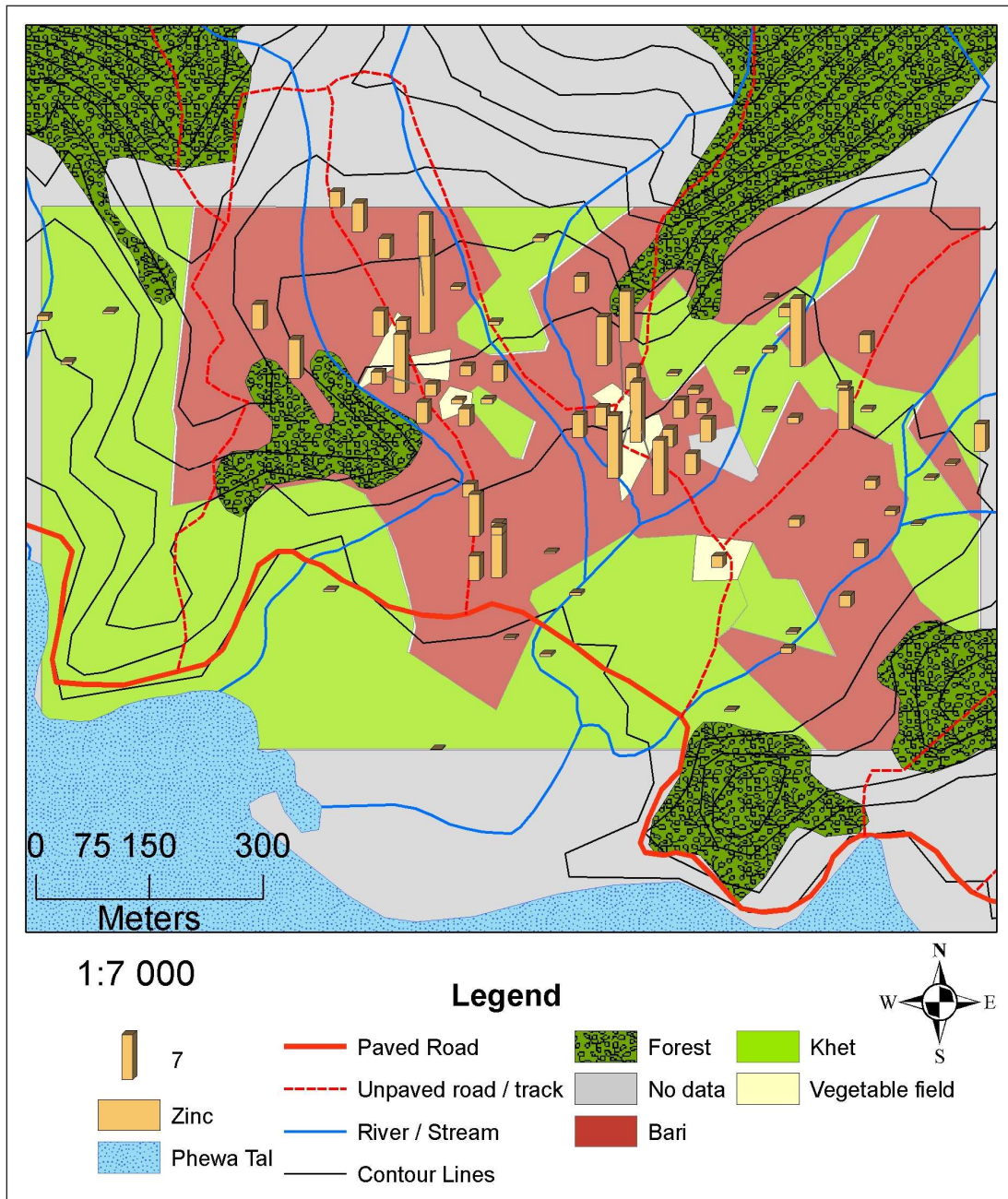


Figure 17: Map of the distributed zinc values.

5.3.2. Spatial autocorrelation.

“If geography is worth studying at all, it must be because phenomena do not vary randomly through space” (O`Sullivan and Unwin 2003: 28)

In a conventional dataset, there may not be any prejudgments of the relationships between the data. Spatial data are special. This is because of spatial autocorrelation which refers to Tobler`s “First law of geography”. This law states that “Everything is related to everything, but near things are more related than distant things”. In other words, before looking at the data we can say that each observation is likely to have values in the same region as the observations around it (Burrough and McDonnell 1998). This is called positive autocorrelation. Negative autocorrelation has the reverse effect, accordingly closer is more likely to be different. It is quite seldom observed, however. The last possibility is zero correlation which implies no recognizable spatial effect. In this case, observed values vary randomly in space (O`Sullivan and Unwin 2003).

The purpose of testing for spatial autocorrelation is that it says something about the spatial nature of the dataset. Thus, if a dataset has positive or negative autocorrelation, the affecting factors are likely to have a spatial preference. For instance, if elevation is a main affecting factor, it should cause a positive spatial autocorrelation.

When zero correlation is found, the affecting factors vary independently of space. Fertilizing could be an example of such, as appliance of fertilizers is basically not subject to spatial positions, but rather field type and rotation practice. (In the very end it is possible that fertilizer appliance is subject to space, though.)

When determining the underlying causes of autocorrelation there are basically two different types, first-order and-second order. First-order is determined by an underlying reason. In my case, such might be geology or fertilizer input. In economic geography one can think of crime as a first-order factor of real estate prices. Second-order is maybe a bit more complicated. This is when an effect takes place between observations. For instance is crime likely to attract crime (O`Sullivan and Unwin 2003).

According to O`Sullivan and Unwin (2003), you can study autocorrelation by creating a semivariogram. A semivariogram gather all possible pairs in the data and plot the square

difference of the attribute in focus (Y), against the distance between the pairs (X) (O'Sullivan and Unwin 2003). Y is defined as $y(S_i, S_j) = \text{var}(z(S_i) - z(S_j))$ where var is variance. If two locations, s_i and s_j , are close to each other in terms of the distance measure of $d(s_i, s_j)$, then you expect them to be similar, so the difference in their values, $Z(s_i) - Z(s_j)$, will be small. As s_i and s_j get farther apart, they become less similar, so the difference in their values, $Z(s_i) - Z(s_j)$, will become larger. (ArcGIS Help Database)

A good example showing positive autocorrelation is my semivariogram of the elevations of my samples (fig 18).

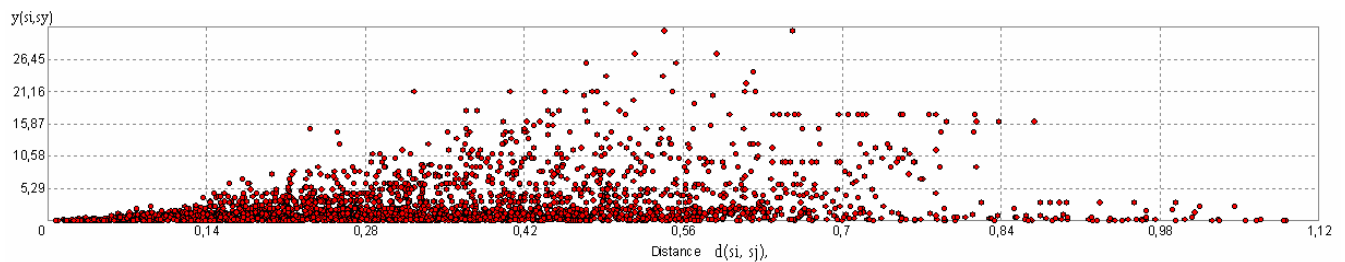


Figure 18: Semivariogram of elevation.

In this case it is easy to identify a pattern. It tells us that if sample x is close to a sample with high elevation, sample x is likely to be at a high altitude as well. However, semivariograms did not show any significant autocorrelation in my zinc and boron data. As figure 19 and 20 illustrates, there are no clear trends. We see that some samples that are very close have extremely different zinc and boron values. These observations conclude that there is no clear positive correlation. As expected, negative correlation is not demonstrated either, as a lot of samples that are close have relatively similar values. The bottom line is that the semivariograms of boron and zinc do not show any significant positive or negative autocorrelation, this indicates zero autocorrelation.

It should be stated that this is a visual interpretation and that the massive number of dots make the semivariograms hard to assess by the human eye.

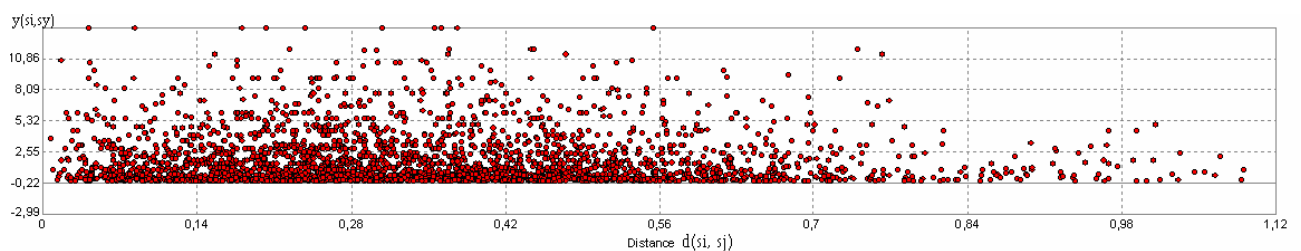


Figure 19: Semivariogram of boron values.

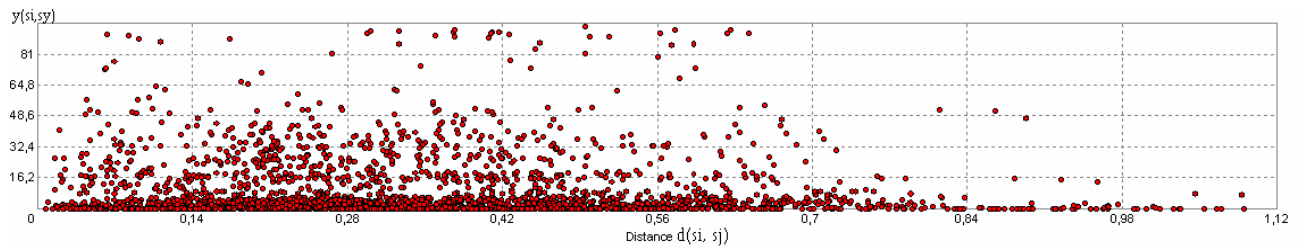


Figure 20: Semivariogram of zinc values.

It is possible to investigate autocorrelation other ways, however. The joins count statistics was first introduced by Cliff and Ord in a book called “Spatial Autocorrelation” from 1973. The method is quite limited considering it only works on binary data, but still it has its contribution. By counting the number of positive (same values) and negative geographic joins (different values), you get an idea of the autocorrelation. These figures can be developed further by testing them against the figures that would be theoretically expected, at a random distribution (O’Sullivan and Unwin 2003).

As I had points with ratio values for the boron and zinc data, the method needed some adjustments before I could take advantage of it. The problem with not having binary data was solved by dividing the data range into two halves. I used the deficiency limit (0,6 ppm) as threshold. By doing this, the joins should be “deficient-deficient”, “not deficient – not deficient” and “not deficient – deficient”. Using 0,6 ppm as threshold may be disputed however, as it is not a natural statistical threshold in the datasets. Dividing the data with regards to deficiency was regarded as more important, although setting a general deficiency limit is a questionable thing to do.

The next problem was to recognize the joins. With point data, this is a bit tricky. Measuring distances and using a certain number of closest points would be a solution. However, given the uneven distribution of samples this seemed as a poor way of doing it. I did not want to risk losing obvious joins and at the same time perhaps include points that were far away from each other. The best idea I could come up with was to make a continuous surface and then determine the joins. One way of doing this is to make circular buffers of each point and then pick out those who have joining borders. This method is quite labour consuming and was rejected when I “discovered” the proximity polygons, also called Thiessen or Voronoi polygons (O’Sullivan and Unwin 2003). The idea is that any location must be closest to one point and is therefore a part of the area connected to this point. The exception is if the location is equidistant to more than one point. Then it lies on a border (O’Sullivan and Unwin 2003).

Proximity polygons seem like a good tool for my purpose. They easily determine which points have common joins (Figure 21).

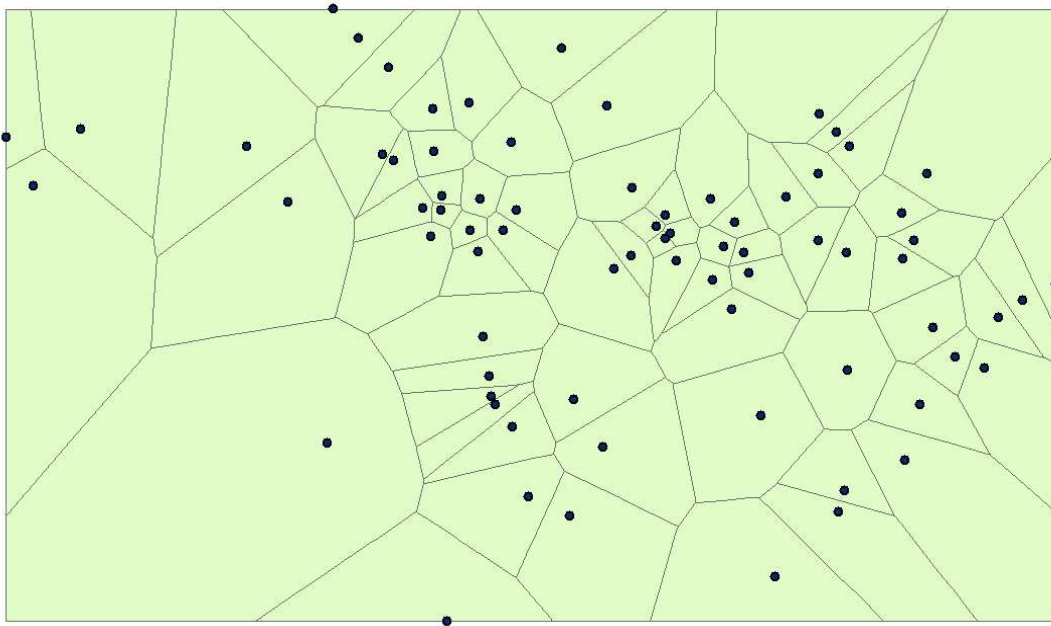


Figure 21: Proximity polygons in field area.

The findings from the joint count statistics are given in table 3. It is not easy to interpret the meaning of these numbers, however. Obviously it looks like there is some kind of trend in the zinc data, as there are 102 joins between points that are not deficient and only 66 joins between deficient and not deficient points. Determining autocorrelation from these numbers is problematic, though. We need to take the number of deficient and not deficient observations as well as the total number of joins into calculation.

Table 3: Actual boron and zinc joins. Def = <0,6 ppm, Nodef = >0,6 ppm.

| Type of join Number of joins | Boron | | | Zinc | | |
|------------------------------------|-------------|-------------|---------------|-------------|-----------------|---------------|
| | Def- Def | Nodef-Nodef | Def- Nodef | Def- Def | Nodef- Nodef | Def- Nodef |
| | 31 | 73 | 89 | 27 | 102 | 64 |

By using these figures we can make a statistical test where we compare the results from table 3 with the outcome of an independent random process (IRP). Such an IRP is mentioned in O'Sullivan and Unwin (2003:188). Translated into this context the expected values are given by

$$E(J_{\text{Def-Def}}) = kp_{\text{Def}}^2$$

$$E(J_{\text{Nodef - Nodef}}) = kp_{\text{Nodef}}^2$$

$$E(J_{\text{Def - Nodef}}) = 2kp_{\text{Def}}p_{\text{Nodef}}$$

when k is the total number of joins, p_{def} is the probability of an sample being coded Def and p_{nodef} is the probability of an sample being coded no-def. The results are displayed in table x.

Table 4: Expected joins from an independent random process (IRP).

| Type of join Number of joins | Boron | | | Zinc | | |
|------------------------------------|--------------|-------------|---------------|-------------|-------------|---------------|
| | Def- Def | Nodef-Nodef | Def- Nodef | Def- Def | Nodef-Nodef | Def- Nodef |
| | 29 | 72 | 92 | 18 | 92 | 83 |

When we compare the results of the IRP (table 4) and the actual joins (table 3), we see that the situation is very much the same with regards to boron. This clearly substantiates the impression given by the semivariogram which suggested that the boron values seemed more or less randomly distributed. It is important to remember that in this statistical test we have limited the data a lot by dividing the data into two values, deficient or not deficient. By doing this, we have “forgotten” the original data range and have therefore lost valuable information. For instance, this test can not tell us anything about the distribution of boron values between 1 and 3 ppm. One solution to this problem might be to do several similar tests with different thresholds. *What it does say is that it the boron deficient and not-deficient samples seem randomly dispersed within my study area.*

As for the zinc, the actual joins differs a lot from the expected joins. We can see that there are some 25% less “nodef-def” joins than expected from the IRP. This indicates that there are some kind of autocorrelation in the zinc data after all. Especially the deficient samples seem clustered. According to the figures, there are 27 joins between deficient samples, while the expected number is only 18. Also the number of joins between not-deficient samples is higher than expected.

What this section tells us is that the samples that are deficient and not-deficient in boron appear to be randomly distributed, while there seem to be some sort of clustering of deficient

zinc samples and not-deficient zinc samples. This will be discussed further in the next chapter.

5.3.3. Spatial interpolation

Spatial interpolation is defined by O`Sullivan and Unwin (2003) as “the prediction of exact values of attributes at unsampled locations from measurements made at control points within the sample area.” This prediction is based on the same idea as spatial autocorrelation; values at points close together in space are more likely to be similar than points further apart (Burrough and McDonnell 1998).

The purpose of using interpolation in my study is to get a better overview of the field area and perhaps reveal some spatial patterns I did not know of. The zinc data might be interesting to interpolate because of the possible spatial autocorrelation discussed in chapter 5.2.1. Areas of somewhat homogenous values should be possible to point out by an interpolation analysis. The boron data, on the other hand, is not suited for interpolation, as there is no spatial autocorrelation. Of course, we could do an interpolation of these data, but as O`Sullivan and Unwin (2003: 221) put it, “we might just as well guess values based on the overall distribution of observed values, regardless of where they are relative to the location we want to predict.”

The most obvious weakness of spatial interpolation is that it tries to say something it really does not have cover for. It is important to keep in mind that it is only a prediction, thus the result should be treated as a prophecy and not reality. The errors of the interpolation might be huge, and most interpolation methods do not give an estimate of these. The exception is the more sophisticated geostatistical interpolations.

To make interpolation as reliable as possible, it is important to have a correct sample pattern. Ideally, samples should be located evenly over the area (Burrough and McDonnell 1998). As pointed out in section 4.3.3., my samples are not at all evenly distributed (Figure 11). This induces problems as some parts of the study area have quite good coverage of samples, while other areas have poor coverage. Consequently, the interpolation will be more trustworthy in some areas than others.

There is a swarm of different ways of doing interpolation. I will only briefly describe the two I have chosen and why. It is normal to divide the deterministic interpolation methods into local and global. Global interpolation methods try to find general surface trends in the data by using a function and determining its exact form by using the control points (O`Sullivan and Unwin 2003). Short-range, local variations are dismissed as random, unstructured noise (Burrough and McDonnell 1998). Because of this, global interpolations are often addressed as inexact, but if one is looking for trends in the data they may be the best option. I find this interesting for my zinc data and have therefore produced a polynomial interpolation.

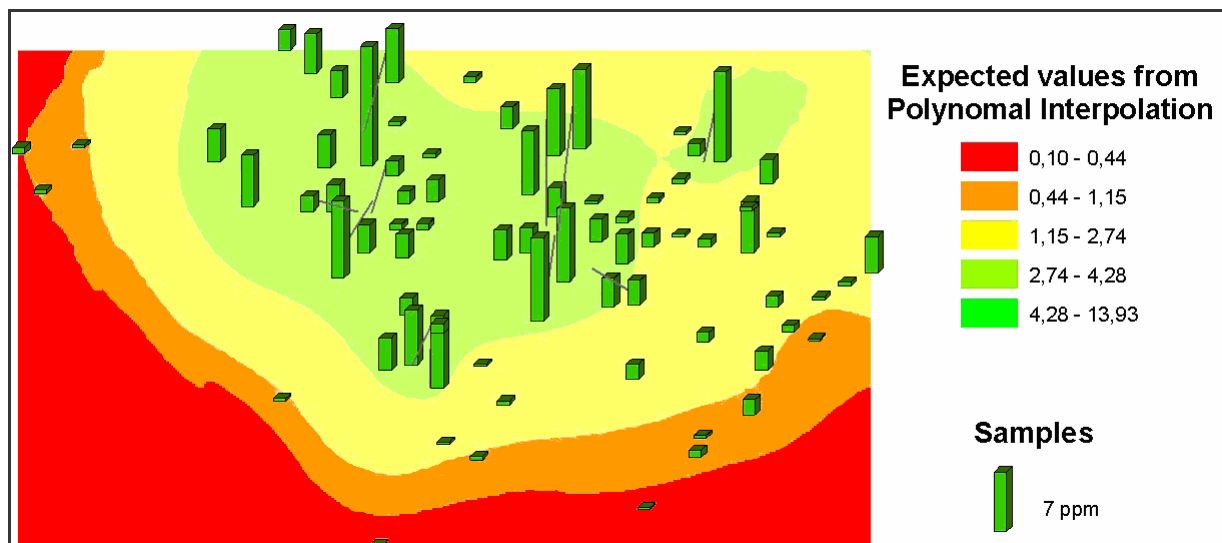


Figure 22: Polynomial interpolation of zinc samples.

What it shows us is that there is a general trend of high zinc values in the centre and northern part of the study area. We can see that there are some low values in the centre of the map as well, though. This demonstrates that zinc levels differ greatly at small distances. Also, it seems evident that the polynomial interpolation is not very trustworthy as we have a lot of low values where the interpolation expects high values. Still, what can be extracted from figure 22 is that there seems to be some sort of spatial pattern, with no high values at the southern, eastern and western fringes of the map. These areas have also some of the lowest values. Of course, the same areas are the ones with poorest coverage of samples and the reliability may therefore be questioned.

Not surprisingly, local interpolation pays more attention to local variations. Each interpolated point is determined by an optional number of weighted neighbours (Hence the most commonly used local interpolation is called Inverse Distance Weighting). I did not find any

satisfactory local interpolation methods for my data, however. It seemed like there were not sufficient samples at the outskirts of the field area to make a good local interpolation.

As a result, I turned to the geostatistical methods of interpolation, mostly known as kriging. Geostatistical interpolations are more sophisticated than deterministic methods. According to Burrough and McDonnell (1998:132), “kriging optimizes interpolation by dividing spatial variation into three components; (a) deterministic variation that can be treated as useful information, (b) spatially autocorrelated, but physically difficult to explain variations, and (c) uncorrelated noise. Put in easier words, kriging tries to combine global trends in the data with a distance weighting approach (O’Sullivan and Unwin 2003). One of the strengths of kriging is that it experiments with different semiovariograms to find the best possible search radii and the best interpolation weights. As mentioned above, geostatistical interpolation will also give an estimate of error. This is very useful because it says something about how reliable the interpolation is.

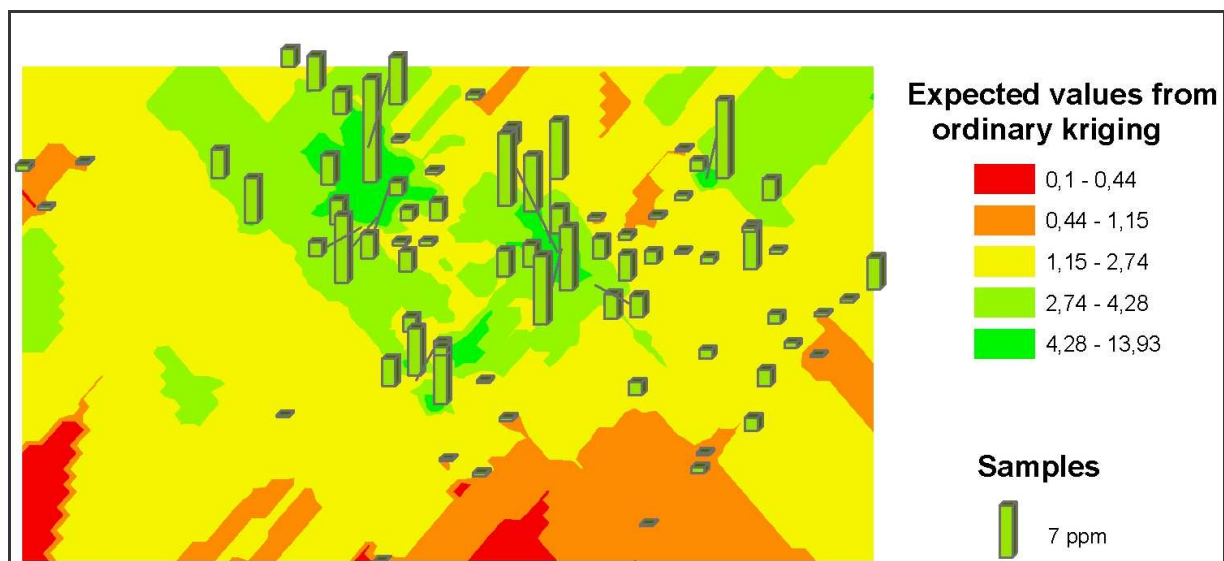


Figure 23: Ordinary kriging of zinc samples.

Figure 23 is an Ordinary Kriging, using maximum five and minimum two neighbours. We can see some clear similarities with the polynomial interpolation. Most of the central field area has high values as well as parts of the northern area. The south, west and eastern parts are generally lower. The estimates are higher than in the polynomial interpolation, though. The average standard error is quite big, some 3,2 with the root-mean square being 2,8. As mentioned, the distribution of samples will have to take some of the blame, but also the outliers in the zinc data play a major part (see figure 9).

Obviously, figure 23 is a lot more fragmented than figure 22, and the kriging shows especially one thing the polynomial interpolation has missed. Between the central area and the north-western corner, there seems to be some kind of belt of low values. Also, in the centre of the study area, we find a tiny crack going from north to south of lower values.

The interpolation of the available zinc samples showed that there are generally highest values in the centre and the northern part of the study area. The kriging confirmed this, but also indicated that the picture is much more complex. As mentioned earlier are my samples poorly distributed within the study area and this severely weaken the quality of the kriging. As a consequence, a lot of noise appears at the edges of the area.

The interpolations have amplified what the spatial autocorrelation analyses indicated; that high- and low zinc samples are more or less clustered. Especially the polynomial interpolation showed a trend of high zinc values in the centre of the field area, which also happens to be the centre of the village. The surrounding area has more or less low zinc values.

5.3.4. Geology and soil cover.

Extensive literature claims that soil cover, geology and nutrients are connected. I have therefore obtained a geology map and soil cover map for my area. The purpose is to investigate them and see if there are any direct links to the boron and zinc distributions.

When we examine the geology map (figure 25), we see that there are a lot of hyalite and quartzite in my study area, which are metamorphic rocks. Soils formed over metamorphic rocks are generally relatively low on boron, according to Victor M. Shorrocks (1997). There is also some highly weathered grit stone present. This is a sedimentary rock and soils formed over such usually contain much more boron than those formed over metamorphic rocks (Shorrocks 1997). Regarding zinc, we know that igneous rocks generally have a low content, while sedimentary and volcanic rocks contain more (Reeves & Brooks 1978). Obviously, this differs a lot. What can be concluded from figure 25 is that the geological picture is mixed and hard to generalize. The geological map is not detailed, however. This makes it hard to compare each soil sample with the type of rock at the same location. Because of this, it is not

possible to actually test if soil boron and zinc values are affected by geology in my study area. The same is the case with soil cover map.

When it comes to nutrient levels in my field area it can be questioned whether geology is likely to have an effect. The soil cover map (figure 24) illustrates that residual soils only cover a limited area and that alluvial soils are dominant. Alluvial soils are transported soils and have therefore no direct relationship to the bedrock at their presence. *This implies that the geology is less important in my study area.*

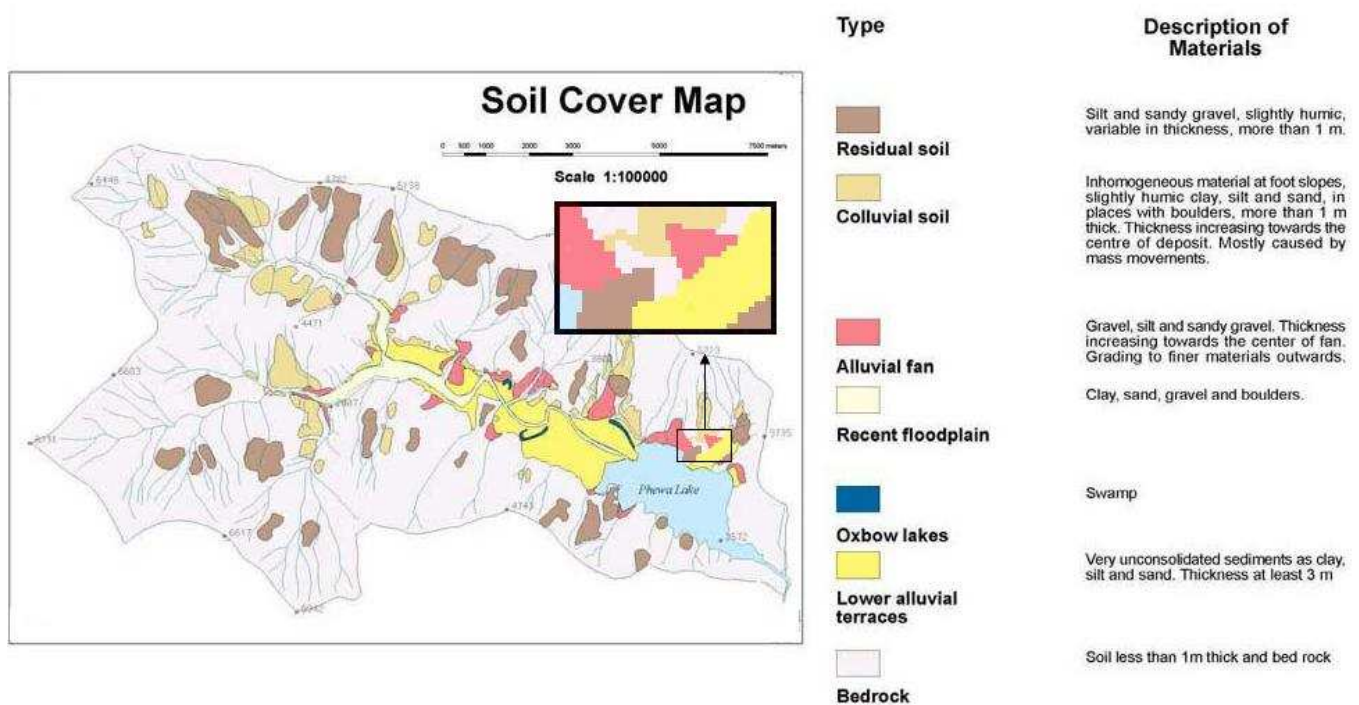


Figure 24: Soil cover map.

The soil cover map has a lot of similarities with the geological map. What is most striking is the uneven distribution of soil materials. The fact that soil texture greatly differs spatially obviously influence the boron and zinc values. As reviewed in section 3.1.3, boron levels seem to be higher in mid-textured soils than in coarse- and fine-textured soils. Zinc is affected the opposite way; lowest values are usual in the mid-textured soils. When we look at the soil map we see that it is dominated by an area called “lower alluvial terrace”. This is unconsolidated sediments such as clay, silt and sand. There are also large alluvial fans and patches of colluvial and residual soils. Common for these are that they contain little clay.

In the same way as the geology, the soils in my study area are complex and my suggestion is that this contributes to the lacking autocorrelation of boron soil values.

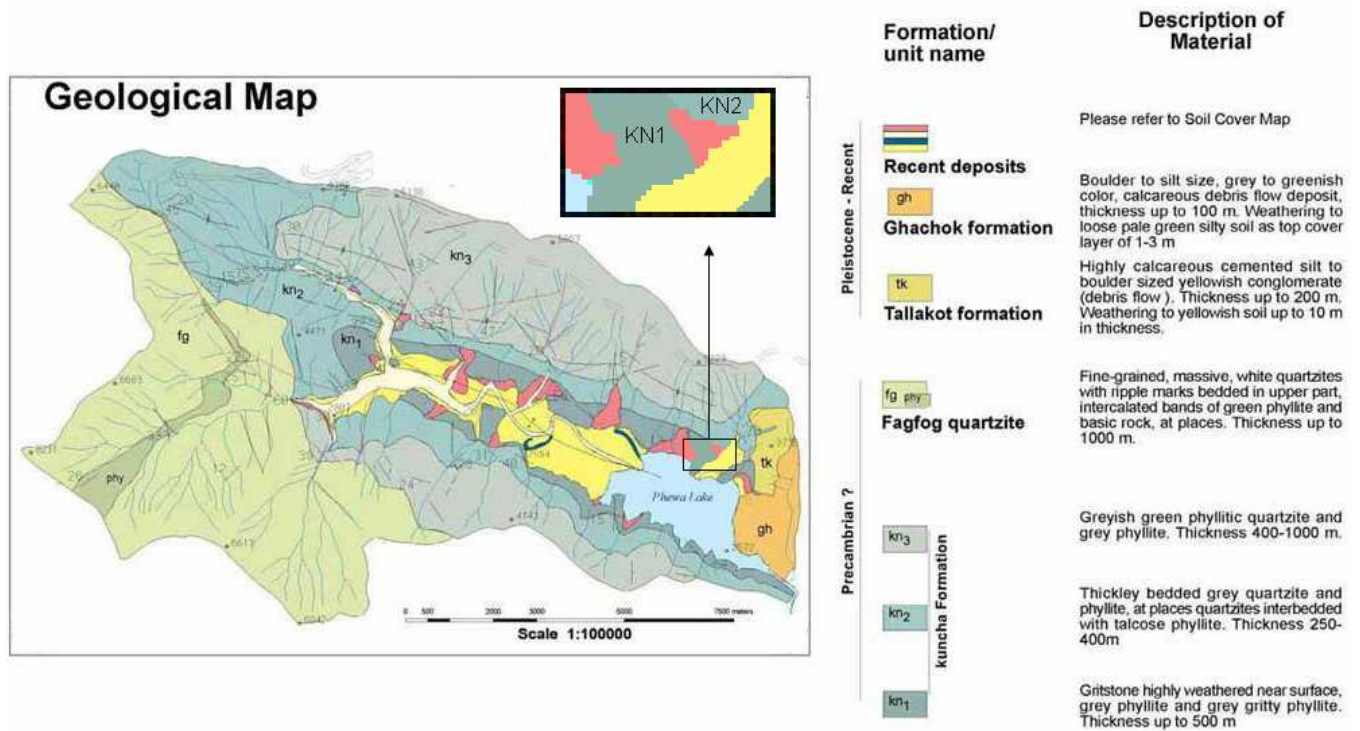


Figure 25: Geological map

5.3.5. Streams and rivers

Several streams are present in the field area. The degree of water flow in each river varies seasonally, but in general they are quite small. It would be interesting investigate if the streams have an influence on available zinc and boron values in the soil. To reveal a possible relationship I divided the samples into two halves; all samples that are 40 meters or closer from a stream and all samples distributed farther away than 40 meters from a river. The findings are illustrated in figure 26. Using different definitions on what is close and far from the river would obviously create different results.

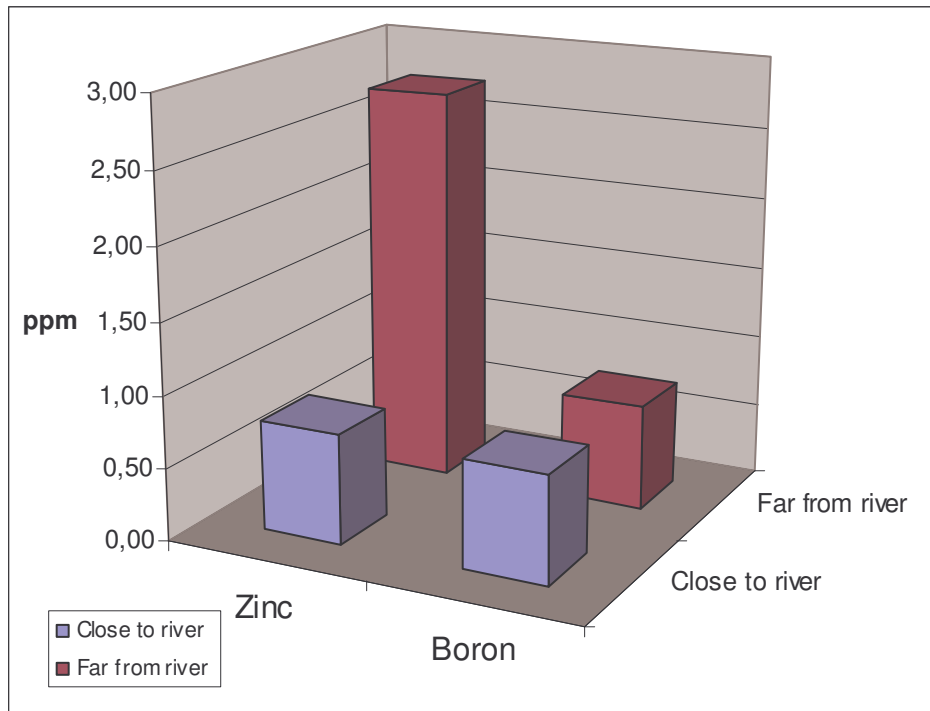


Figure 26: Relationship between distance to river and boron and zinc. The median boron and zinc value is used in each category.

Available boron is very much the same close and far away from the river. This indicates that there is no relationship between available soil boron and distance to river.

The figure seems to demonstrate a connection between available zinc and distance to river, though. The “far from river” category has much higher available zinc values than the “close to river” category. A possible natural explanation can be erosion when the rivers exceed their barriers.

The relationships shown in figure 26 can also be explained by the distribution of land categories. It is natural that there are more khet than bari along the streams, as khet very often are found on the relatively flat plains. Also, khet is irrigated and therefore needs streams in the vicinity. Figure 27 illustrates the distribution of land categories relative to the distance to streams. It concludes that bari and vegetable fields mostly are sited far from streams. The majority of the khet is close, however. This might also have something to do with the fact that bari often is sited near the houses and houses are kept away from the streams, due to flooding hazards.

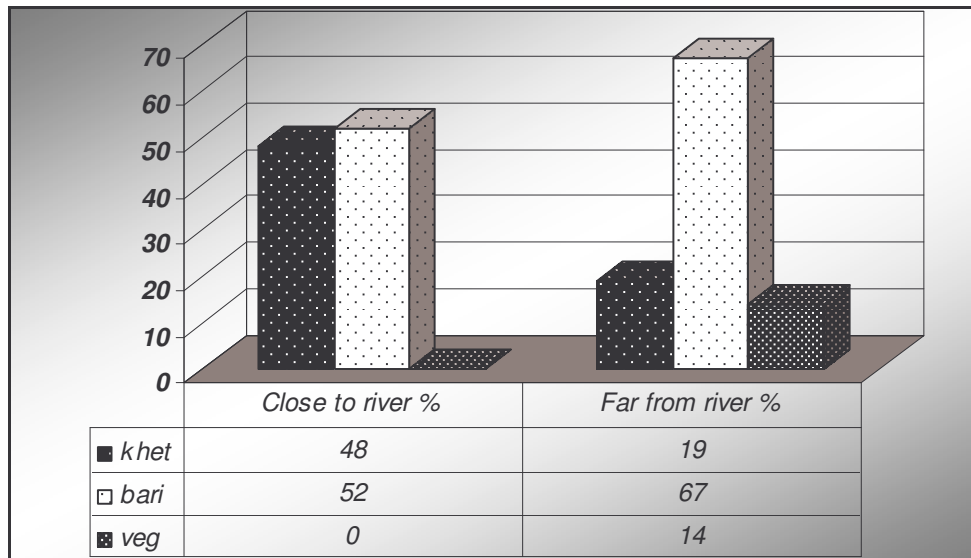


Figure 27: Relationship between land categories and distance to river

Bottom line is that available zinc tends to be low close to rivers. It is hard to determine if there is a direct relationship, as it could also be due to the distribution of land categories and the different farming practices exercised on them.

Land categories as explanation to zinc deficiencies will be investigated further in the following.

5.4. FARMING SYSTEM ANALYSIS

In this section I will try to sum up my most important data concerning the farming system in the field area.

5.4.1. Rotation cycles

As discussed earlier in section 3.2.2, the main nutrient loss from agricultural soil is usually the crop itself. The crops and the rotation cycles are therefore a possible explanation to nutrient deficiencies. However, to make a reliable quantification of this is very hard. First of all, you would have to calculate how much nutrients different types of plants take up. This will probably induce problems itself and to get the picture right, an estimate of the varying plant density in each field would be needed as well. Also, taking into account the effect of some fields lying fallow parts of the year is problematic. I therefore simplify things and aim my main focus on the number of rotations per year.

When taking the first quick glance at my rotation cycle statistics, there are some clear divides in the data. These are generally following the land categories.

In addition to bari and khet, there are some vegetable fields in the study area. The rotation cycle in these are mostly based on seasonal vegetables such as potato, radish, beans, cauliflower, garlic, sweet potato, squash, carrot and tomatoes. Some peasants also have fruit trees and some grow marihuana in their vegetable patches. Overall, the rotations seem quite intensive as vegetables are grown all year around. Vegetables in general are known to be very nutrient demanding, taking up larger quantities than for instance grain species.

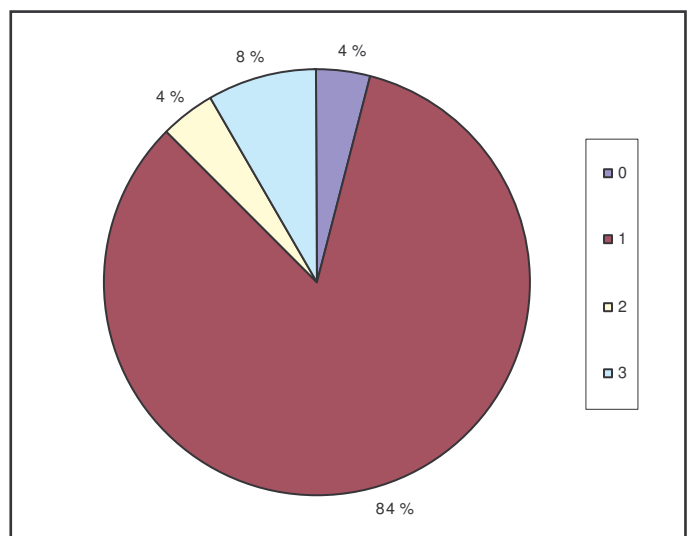
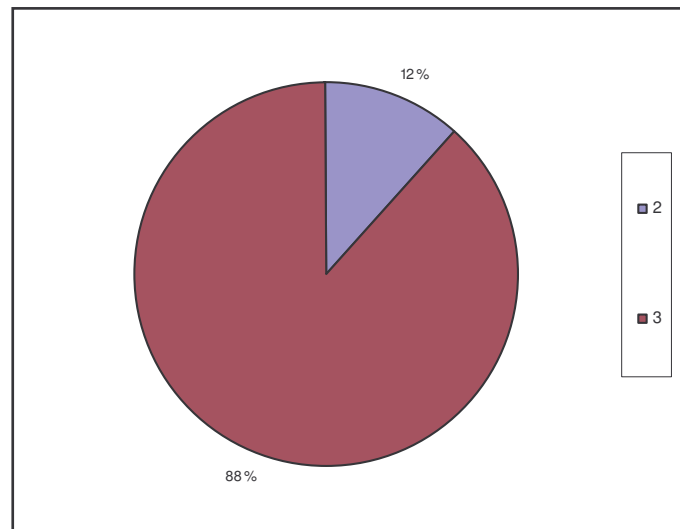


Figure 28: Number of annual crops in khet fields.

Most of these vegetables may be characterized as HVC`s. Due to the area being close to the big city of Pokhara, market connections are excellent and chances to sell HVC`s are good. There are a lot of tourist restaurants in Pokhara and I was told that these buy lots of locally grown vegetables. The relative high number of vegetable patches can therefore easily be explained. It is simply a good way for the semi-subsistence peasants to create an income without using too much of their land.

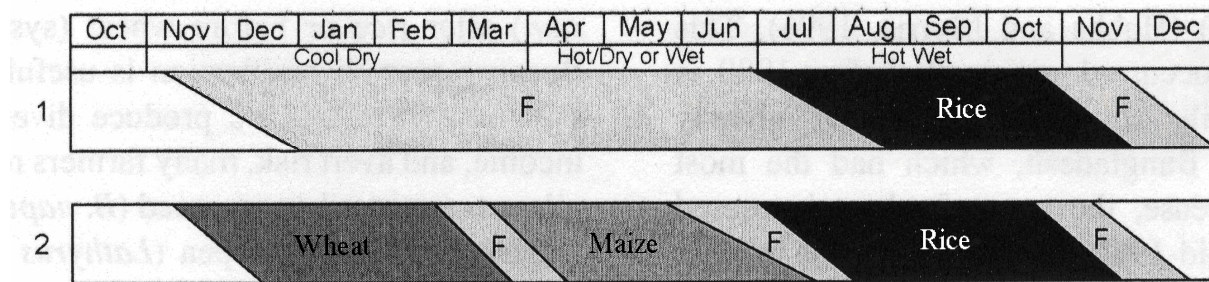
Regarding the samples taken from khet fields, all but four samples have the rotation “rice-pasture”. Rice is grown from July to November (dependent on when the monsoon strikes), and the pasture period fill up the rest of the year (figure 30). The pasture period is much the same as a fallow period. Two of the four khet fields not using the “rice-pasture”-



rotation are using the most usual bari rotation cycle, which is “Maize-Rice-Wheat/Mustard”. This is a much more demanding cycle, giving the soil little or no time to recover from the previous cultivation. The two remaining sample fields were one “rice-wheat”-rotation and a field with pasture all year around.

Overall, the rotation cycles in the khet fields are especially intensive, regarding the number of rotations in a year. It can be argued that the pasture is having a diminishing effect on micronutrient levels, as there is stock grazing all year around, but at the same time there is a transfer of some micronutrients back through manure. This will be discussed later on.

“Maize-Rice-Wheat” is the most usual bari rotation. However, compared to khet, there are more variations in the bari fields. In addition to the mentioned rotation I have also found “Maize-Rice-Mustard”, “Maize-Vegetables”, “Maize-Millet”, “Maize-Vegetables-Mustard”, “Maize-Millet-Maize”, “Maize-Rice-Potatoes” and “Maize – Potatoes”. With only a few exceptions, rice is present in all fields and is obviously the most important crop. Maize (spring) and wheat (fall-winter) are also very important too most peasants in my field area.



**Figure 30: Typical khet (1) and bari (2) rotations in the field area (F = fallow).
Adopted from Timsina and Connor (2001).**

In addition to these rotations, relay- and inter cropping is very usual in the bari fields. For instance is mustard almost on all occasions intercropped with wheat. In the same way is millet often sown along with rice. Various vegetables and seeds, such as pumpkins, cucumber and beans, are usually relay- and inter cropped with maize in the spring and early summer.

There is a dramatic difference in the number of rotations when we compare khet and bari. Figure 30 shows us that almost all peasants have three rotations on their bare fields. In khet we remember that one was the most usual number of rotations. This obviously leads to a less intensive extraction of micronutrients in the khet soils. The nutrient mining in the bari fields is likely to be quite intense, on the other hand. In addition to having more rotations, the intercropping extracts nutrients as well. The effect of relay- and inter cropping may not be serve, however, as these plants are likely to take advantage of micronutrients that the main crop largely ignores, due to different nutrient requirements and different root lengths. Also, erosion may decrease as the vegetation cover is becoming denser.

Bottom line is that there seem to be a big difference in rotation intensity between bari and khet. Khet has generally not intensive rotation cycles, while bari is the opposite. This is a bit surprising as a lot of literature refers to the contrary (Turner and Brush 1987; Blaikie and Brookfield 1987). Two explanations might be the high temperatures and high annual precipitation in Pokhara. This extends growth seasons and makes bari suitable for rice cultivation, although it is not irrigated.

These findings should imply, however, that bari is more exposed to micronutrient deficiencies than khet due to cropping intensity. This corresponds well with hypothesis number three and will be discussed in chapter 6.1.2.



Figure 31: Picture of khet fields lying fallow. The patches to the left are recently ploughed and ready for rice cultivation once the monsoon starts. The others were used as grazing area for buffaloes when the photo was taken.

5.4.2. Fertilizing practices.

As suggested by the literature search, the main fertilizers applied in the study area are Urea and DAP, in addition FYM. In fact, none of the peasants participating in the field work applied micronutrient fertilizers or what they call vitamins. Nobody used any kind of green manure either. One single peasant applied potassium (50kg per Ha) on his bari field and two peasants applied some poultry manure. Except for that, it was all about DAP, FYM and Urea. FYM was most popular, being applied to 59 of the 74 fields investigated. Obviously the quantities were also much bigger than with the chemical fertilizers. The average use of FYM on all fields was some 16 tons per ha. The differences from field to field were large, though. Some applied the moderate amount of 1,5 tons of FYM per ha, while two peasants used as much as 100 tons per ha. The DAP and Urea was applied to 46 and 51 fields respectively. Also here were there big differences regarding quantity, urea varying from 4 to 320 kg per ha and DAP from 2 to 200 kg per ha. The average amounts was 33 kg per ha for DAP and 43 kg per ha for Urea. Data on chemical fertilizer use in Nepal is scarce, but Rimal et al. (1997)

have figures from 1995 saying that the average chemical fertilizer appliance for Gandaki district was 36 kg. My field area have an average of 75 kg per ha and is therefore above the FAO average, but it is unrealistic to think that the 1995 figures are valid today. Still, it gives us a hint saying that the average for my field area is not way of the district average.

As in the rotation cycles section, I think it is appropriate to divide the fertilizing practises by land classification. What is clear is that the farmers treat the two main land categories, khet and bari, very differently. FYM, which is regarded as the most important input by the peasants (Andersen 2001), is used in very little amount on khet fields. On bari, vast quantities of FYM are applied. This is not surprising, as we found in the last section that bari generally has a higher rotation intensity than khet. It is therefore logical that bari get the most FYM. However, when we look at the chemical fertilizers, it is the other way around. On average, khet get 2-3 times more DAP and Urea than Bari.

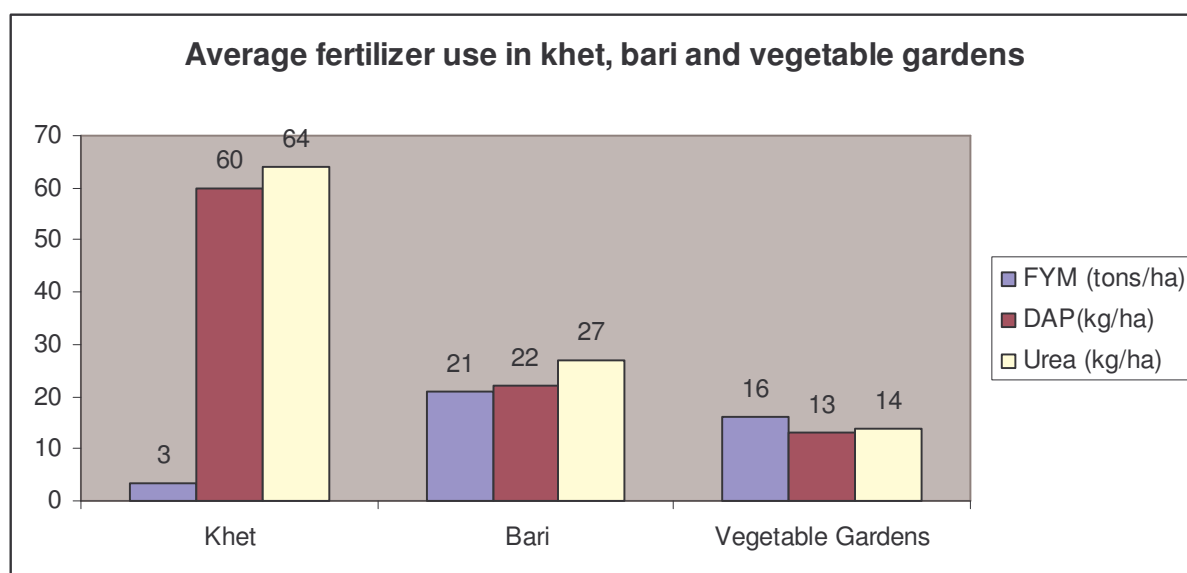


Figure 32: Histogram of average fertilizer use in land categories.

This means that in khet, micronutrient input through fertilizers is very scarce. The free grazing animals in the fallow period may supply a small amount of micronutrients, however (Carson 1992). These animals are also likely to contribute somewhat to rising organic matter content of the soil. However, with so small amounts of FYM applied, the organic matter content of the khet soils is probably very low. As discussed in chapter 3.1.3, low organic matter content reduces available zinc considerably. *The bottom line regarding fertilizer input in khet is that although considerable amounts of DAP and urea are applied, the input of*

micronutrients are as good as not existing. Irrigation waters and weathering may to some extent have a positive effect, but these issues are not covered by this study.

Vegetable gardens get less fertilizer than Bari. This is surprising, as vegetables need a lot of nutrients to grow. One can understand it though, as the main crops for the semi-subsistence farmers are grown on the bari terraces. These crops determine how much food the family will have available, and is therefore more important than the cash crops. Most vegetable gardens are close to the animal stalls and the vegetables may therefore take advantage of urine and manure runoff. This is hard to assess and quantify, but probably very important and may have big impacts on nutrient levels in the vegetable gardens. This can also explain why fertilizer inputs are low, compared to bari.

Bari terraces have the highest input of FYM, 21 tons per ha on average. Compared to the findings of Carson (1992) this amount of FYM is not extremely high, although the bari rotation cycles in my field area are extremely intensive. Still, micronutrient inputs in bari are generally much higher than in khet, due too the fact that very little FYM is applied to khet. Moderate amounts of chemical fertilizers are used in bari.

The presence of micronutrient deficiencies is widely established in Nepal (at least at the academically level), and that is why I was surprised that none of the peasants used any kind of chemical micronutrient fertilizers. As discussed earlier, the two main constraints regarding use of this kind of fertilizers are knowledge and availability.

All the peasants who used chemical fertilizers stated the local Agro-vet as their source of fertilizer information. This is the same place as they buy the goods. I paid the two Agro-vets closest to my field area a visit to investigate their supplies and perhaps their knowledge concerning their fertilizers. These stores had good connections as Pokhara is a big city in the central Nepal. According to one salesman, they had everything the peasants wanted. When asked what fertilizers he sold most of, he answered DAP and Urea. He also mentioned that they did sell some borax, “vitamin” and a couple of other “special” inputs. The people who bought these “special” types of fertilizer were those owning a lot of land.

As far as I could determine did the staff at the two Agro-vets not demonstrate a lot of knowledge regarding the goods they sold. “Vitamin” was explained as a general “growth booster”. The content of the small bottles was never mentioned. Micronutrient deficiency

problems were not really discussed, although I tried to raise the subject. My thoughts were that the staff of these two stores would not be able to give the semi-subsistence peasants well enough fertilizing advices to cope with a micronutrient deficiency. The Agro-vets did have supplies of some micronutrient fertilizers, though.

Consequently, knowledge was the most likely factor prohibiting the peasants from using chemical fertilizers with micronutrients. This point of view is also backed by my conversations with the peasants. They showed no understanding of nutrients and had the comprehension as Andersen (2005) wrote of; that all input has a “power” effect. In this hierarchy of fertilizers, FYM was regarded as the best and most powerful. According to the peasants, chemical fertilizers (represented by DAP and Urea) had a good temporary effect, boosting the crops. They had found several drawbacks with chemical fertilizers as well, though. The effect did not last as long as with FYM and it was claimed that the soil got “addicted”. By “addicted” they meant that that if they stopped applying DAP and Urea, the fields would become less productive than before they started using chemical fertilizers. In addition, the peasants argued that DAP and Urea would impoverish the fields in the long run and that they would have to increase the amount of fertilizers to sustain the crops. Prasad and Sinha (2000) found that this might very well be the case if only chemical fertilizers are applied. Their opinion is that applying both chemical fertilizers and FYM is the only way of keeping the fertility up in intensive, Nepalese farming systems.

In the same way as Carson (1992) and Andersen (2001) report, also the peasants in my field area complained that the soil got cloddy and hard to till after applying chemical fertilizers. In fact, although DAP and Urea was much used, the peasants had a largely negative view on these. As mentioned, FYM seemed almost glorified. The majority of the peasants stored their compost in a heap before transporting it into the fields. Most of those who had animals also used the bedding in their compost heap. According to Andersen (2001), mixing animal bedding with compost is likely to improve the composting process and consequently raise the nutrient levels of the compost.

Summing up the fertilizing practices in my study area, the most important seems to be the lacking input of micronutrient fertilizers. Although FYM inputs are relatively high in bari, it is questionable if this is enough to sustain adequate micronutrient levels under such a nutrient

demanding cropping regime. Regarding the khet fields, there seems to be very little micronutrient input. With close to no FYM, almost all nutrient input is macronutrients.

All peasants who obtain fertilizer recommendations get them from the local Agro-vet. These recommendations are very general, perhaps even poor. All focus seems to be on macronutrients, although fertilizers containing micronutrients are available.

5.5. CORRELATION ANALYSIS AND STATISTICAL RELATIONSHIPS

Correlation analysis is used to describe the strength and direction of the linear relationship between two variables (Pallant 2005). The mostly used correlation coefficient is probably the Pearson Product-Moment Coefficient. This is a powerful parametric method. Unfortunately, parametric correlation analyses make some assumptions about the data. One such assumption is that the data is normally distributed. As we saw in the exploratory data analysis, this is not the case for all of my data. I have therefore chosen a non-parametric correlation tool. It is called Spearman's Rank Order Correlation. A drawback with this method is that it is less powerful than its parametric cousins (Pallant 2005).

The following chapters will discuss the main findings in table 5.

Table 5: Correlation table

| | Land Category | Size of field | Buffaloes | Cows | Oxes | Goats | Animal food | Crop | Animal bedding | FYM | Poultry | Urea | Potassium | DAP | Elevation | pH | Available zinc ppm | Available boron ppm |
|-----------------|---------------|---------------|-----------|-------|-------|-------|-------------|-------|----------------|-------|---------|-------|-----------|-------|-----------|-------|--------------------|---------------------|
| Land Category | 1,00 | -0,05 | -0,04 | -0,03 | 0,01 | -0,03 | -0,11 | 0,10 | -0,38 | -0,52 | 0,02 | 0,20 | -0,10 | 0,26 | -0,22 | -0,13 | -0,36 | 0,02 |
| Size of field | -0,05 | 1,00 | 0,33 | 0,13 | 0,44 | 0,27 | 0,17 | -0,01 | 0,21 | -0,23 | 0,05 | -0,01 | -0,07 | 0,19 | 0,14 | -0,19 | -0,24 | -0,03 |
| Buffaloes | -0,04 | 0,33 | 1,00 | 0,14 | 0,47 | 0,39 | -0,11 | 0,27 | 0,46 | 0,13 | 0,01 | -0,07 | 0,17 | 0,04 | 0,09 | -0,15 | -0,02 | -0,03 |
| Cows | -0,03 | 0,13 | 0,14 | 1,00 | 0,24 | 0,27 | -0,22 | 0,08 | 0,13 | 0,01 | 0,09 | 0,10 | -0,06 | 0,14 | 0,00 | -0,03 | 0,03 | 0,17 |
| Oxes | 0,01 | 0,44 | 0,47 | 0,24 | 1,00 | 0,51 | 0,08 | 0,00 | 0,19 | -0,24 | -0,02 | 0,02 | -0,11 | 0,24 | -0,02 | -0,16 | -0,23 | -0,06 |
| Goats | -0,03 | 0,27 | 0,39 | 0,27 | 0,51 | 1,00 | -0,19 | 0,10 | 0,08 | -0,19 | 0,11 | -0,16 | 0,13 | 0,10 | 0,21 | -0,15 | -0,05 | 0,00 |
| Animal food | -0,11 | 0,17 | -0,11 | -0,22 | 0,08 | -0,19 | 1,00 | -0,05 | 0,03 | -0,05 | 0,03 | 0,15 | 0,02 | 0,11 | -0,06 | -0,04 | -0,06 | -0,33 |
| Crop | 0,10 | -0,01 | 0,27 | 0,08 | 0,00 | 0,10 | -0,05 | 1,00 | 0,15 | 0,30 | 0,10 | -0,21 | 0,07 | -0,23 | 0,25 | -0,09 | 0,22 | 0,04 |
| Animal bedding | -0,38 | 0,21 | 0,46 | 0,13 | 0,19 | -0,08 | -0,03 | -0,15 | 1,00 | 0,51 | 0,12 | -0,24 | -0,09 | 0,14 | -0,04 | 0,20 | 0,30 | 0,01 |
| FYM | -0,52 | -0,23 | 0,13 | 0,01 | -0,24 | -0,19 | -0,05 | 0,30 | 0,51 | 1,00 | -0,08 | -0,25 | 0,13 | -0,33 | 0,24 | 0,23 | 0,38 | 0,06 |
| Poultry | 0,02 | 0,05 | 0,01 | 0,09 | -0,02 | 0,11 | 0,03 | 0,10 | 0,12 | -0,08 | 1,00 | -0,15 | -0,02 | -0,12 | -0,10 | -0,19 | 0,01 | 0,02 |
| Urea | 0,20 | -0,01 | -0,07 | 0,10 | 0,02 | -0,16 | 0,15 | -0,21 | -0,24 | -0,25 | -0,15 | 1,00 | -0,03 | 0,74 | -0,19 | -0,32 | -0,40 | -0,18 |
| Potassium | -0,10 | -0,07 | 0,17 | -0,06 | -0,11 | 0,13 | 0,02 | 0,07 | 0,09 | 0,13 | -0,02 | -0,03 | 1,00 | -0,03 | 0,00 | 0,06 | 0,04 | -0,06 |
| DAP | 0,26 | 0,19 | 0,04 | 0,14 | 0,24 | 0,10 | 0,11 | -0,23 | -0,14 | -0,33 | -0,12 | 0,74 | -0,03 | 1,00 | -0,12 | -0,29 | -0,44 | -0,12 |
| Elevation | -0,22 | 0,14 | 0,09 | 0,00 | -0,02 | 0,21 | -0,06 | 0,25 | 0,04 | 0,24 | -0,10 | -0,19 | 0,00 | -0,12 | 1,00 | -0,26 | 0,33 | 0,06 |
| pH | -0,13 | -0,19 | -0,15 | -0,03 | -0,16 | -0,15 | -0,04 | -0,09 | 0,20 | 0,23 | -0,19 | -0,32 | 0,06 | -0,29 | -0,26 | 1,00 | 0,26 | 0,12 |
| Available zinc | -0,36 | -0,24 | -0,02 | 0,03 | -0,23 | -0,05 | -0,06 | 0,22 | 0,30 | 0,38 | 0,01 | -0,40 | 0,04 | -0,44 | 0,33 | 0,26 | 1,00 | -0,02 |
| Available boron | 0,02 | -0,03 | -0,03 | 0,17 | -0,06 | 0,00 | -0,33 | 0,04 | -0,01 | 0,06 | 0,02 | -0,18 | -0,06 | -0,12 | 0,06 | 0,12 | -0,02 | 1,00 |

5.5.1. Land categories.

I have given the difference between bari and khet much attention until now. So the obvious question that comes to mind is; are there any differences between khet and bari when it comes to available zinc and boron levels? The correlation analysis suggests that there is a relationship between available zinc and land categories (- 0,36). Figure 33 clarifies this by showing frequencies of available zinc values in bari, khet and vegetable fields. As we can see there are some dramatic differences. In the bari histogram, there are most samples between 0 and 4 ppm and from there the frequencies are declining with rising values. The declining trend applies for the khet histogram as well, but the data range is much shorter. What is really striking is that more than half of the samples from khet are below 0,5 ppm.

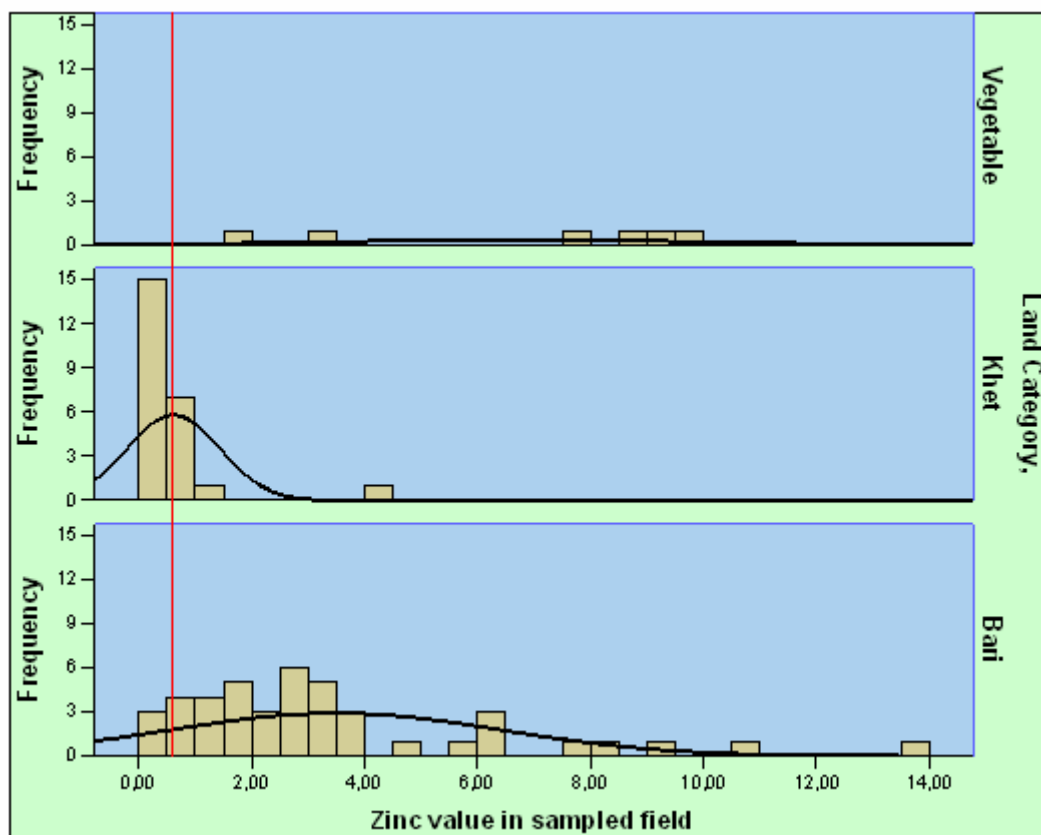


Figure 33: Histogram with normal curve showing frequencies of zinc values. The red line illustrates the deficiency limit.

Compared to bari and the dataset as a whole, this is a very high percentage. The rest of the khet samples also have low available zinc values. Except from two, all samples have less than

1 ppm available zinc. The vegetable fields do not have any really low zinc values, but it is dangerous to put any weight on this, as I have only investigated six vegetable gardens.

The histogram of boron values (fig 34) differ from the one with zinc. First of all, the scale is smaller. The maximum available boron value is 1,65 ppm. As we can see, vegetable gardens, khet and bari all have quite low as well as high boron values. All three trend lines are also more or less bell shaped. This means that there are most samples in the middle of the data range and fewer towards the extreme values (both high and low). In deed, the bari and khet histograms look very much the same. *What can be drawn from this is that boron distribution does not seem to vary accordingly to land categories.*

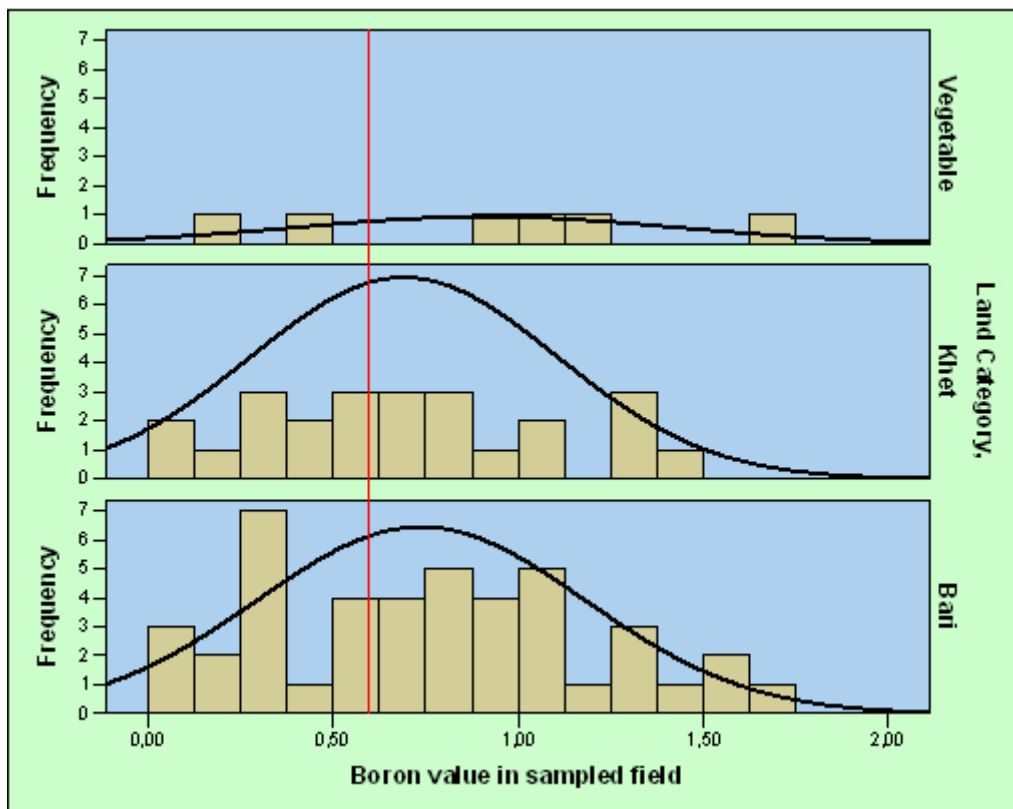


Figure 34: Histogram with normal curve showing frequencies of boron values. The red line illustrates the deficiency limit.

In addition to available zinc and boron, I investigated how pH-levels were distributed within the khet and bari categories. The khet data had a couple of extreme outliers. As of this the average pH was not lower than 5,3. However, some 50% percent of the fields had lower pH than 5. In bari, only 9 % of the fields had a lower pH than 5, and the average was 5,7. As we have seen in an earlier chapter, lowering the pH should lead to higher zinc availability.

Despite of this, zinc levels are lower in khet than in bari. Actually, the correlation analysis show a positive correlation between pH and available zinc (0,26). It is dangerous to say that this is a direct relationship, though.

To briefly sum up, the most important findings in this section are that the available zinc values in khet are much lower than in bari and vegetable gardens. Boron values seem to vary unaffected by land category. Off course, these findings do not say anything about the underlying causes of the varying zinc and boron values.

5.5.2. Number of rotations.

A logic derivation from the analysis of land categories is to investigate if numbers of rotations affect the zinc and boron content in the soil. The correlation coefficient of boron and rotations is very close to 0 (Correlation analyses of rotation numbers are excluded from table 5, due to a problem with lacking values in vegetable fields). It seems therefore like it is no connection between the two. On the contrary, zinc and number of rotations had a positive correlation coefficient of 0,43. This should suggest that rising number of rotations lead to higher zinc values. It does not really make any sense though. Plants that are harvested do not supply more micronutrients to the soil than they extract.

As mentioned in the previous section, almost all khet fields had only one rotation and khet had generally lower zinc content than bari and vegetable fields. This is a likely to explain why the correlation between zinc and number of rotations is high. It does not give us any new answers and suggests that something else is affecting zinc and boron content to a greater degree than number of rotations.

5.5.3. FYM and chemical fertilizers.

As reviewed in chapter three, fertilizers are the main input of nutrients to agricultural soils. Investigating the relationship between zinc, boron and fertilizers would therefore be interesting. The two chemical fertilizers used do not contain considerable amounts of micronutrients. They should therefore not have direct impacts on zinc and boron levels. Still, I found a negative correlation of -0,44 between DAP and available zinc and almost similar figures for available zinc and urea. This is probably not directly caused by the appliance of DAP and Urea, though. One explanation may be that DAP and Urea are mostly applied to khet and khet generally has low zinc values.

FYM is more interesting because it contains considerable amounts of micronutrients. The correlation analysis produced a 0,38 correlation coefficient for available zinc and FYM. To further illustrate this relationship I have made a figure using binary categories. In figure 36 the zinc categories are divided at 0,6 ppm zinc (deficiency limit) and the FYM categories are divided into “applying FYM” and “not applying FYM”. Figure 35 shows that almost 70 percent of those fields that did not receive any FYM are zinc deficient. Only 21 % of those fields that did get FYM were zinc deficient. In their study, Chaudhary and Narwal (2005) found that there was a significant increase in DTPA extractable zinc in the soil with increasing dose of FYM application. My data seem to indicate the same. One can not be certain that adding FYM is the magic trick, though. It is difficult to really determine what the cause of low available zinc

levels is. As previously discussed, FYM is generally not applied to khet and khet soil has generally low available zinc. One can therefore rightfully ask if it is this correlation we really see in figure 35. *Still, small amounts of FYM application seem like a logical explanation to low available zinc level.*

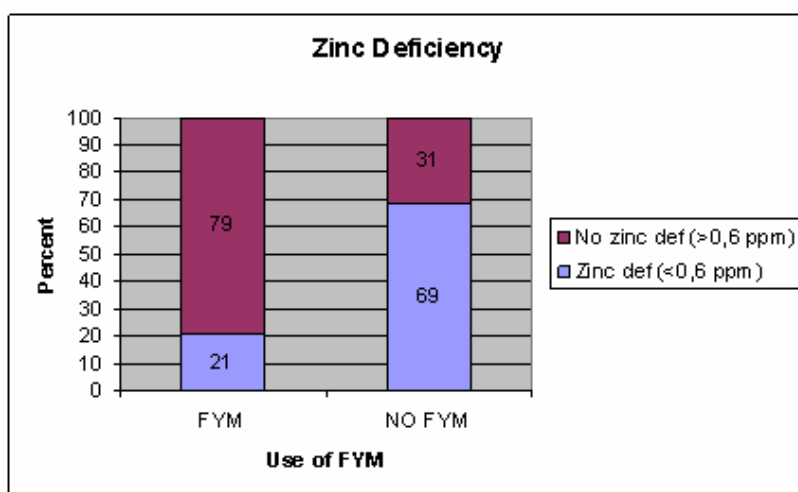


Figure 35: Illustration of the relationship between zinc deficiency and appliance of FYM

Now what about the relationship between available boron and fertilizer use? I used the same test as on the available zinc, but no interesting findings emerged. I simply could not find any good correlations or indications on what caused the boron values to vary. FYM nor chemical fertilizers showed any impact on available boron. This supports the findings in chapter 5.3.2., saying that available boron values seem to vary randomly.

In his study in Koshi Hills, Andersen (2001) found that the peasants there had different routines when it came to adding animal bedding to their FYM. The same is the case in my study area. Of the 54 fields that received FYM, eleven were without animal bedding. The median of available zinc in these was 1,79 ppm and available boron 0,68 ppm. The available zinc and boron medians of the remaining 43 fields were 2,60 ppm and 0,75 ppm respectively. The averages of the data pretty much reproduce the medians. What we can make of this is that there are virtually no difference between those who do and those who do not use animal bedding when it comes to available boron. The interesting part is once again in the zinc department. The difference between 1,79 ppm and 2,60 ppm is considerable and indicates clearly that using animal bedding in the FYM is desirable if one is to raise available zinc levels in the fields. The relationship is also indicated by the correlation analysis with a positive coefficient of 0,3.

The best correlation coefficient found in the dataset was the one between urea and DAP (0,74). This is not at all surprising as these two chemical fertilizers are very often used together, one before sowing and one during the growth period.

Summing up this section, I have found indications saying that applying FYM reduces zinc deficiency. Also, animal bedding seems to have a positive effect on available soil zinc. I did not find any such correlations regarding available boron, however.

5.5.4. Animal food source.

The correlation analysis did only reveal one significant relationship that included available boron. This is the one connecting available boron and animal food source with a correlation coefficient of 0,33. After further analysis of this relationship I found that the data are not solid, but still interesting enough to be mentioned. The majority of the peasants fed their animals a mixture of straw from their crops and grass. The green fodder category consists of grass from fields lying fallow as well as leaves from trees. A couple also gave some sort of grain feed to their stock, while five peasants only fed their stock straw. As we can see from figure 36, there are some major differences in the three categories. Especially if we look at the median values, the peasants who only feed their stock straw score low on available boron in their fields. *Interpreting this, it is logical to think that feeding the stock green fodder contributes to raising boron values of the FYM.*

However, as mentioned earlier the data is poor. It is poor because almost all of the peasants give straw and grass to their stock. As only five peasants are in the “only straw” – category, the amount of data is too small to be able to say anything certain. Figure 36 is interesting though and further studies on the subject might be suggestive.

The remaining thirteen peasants in the study did not have any animals and their available boron values are therefore not included in figure 36.

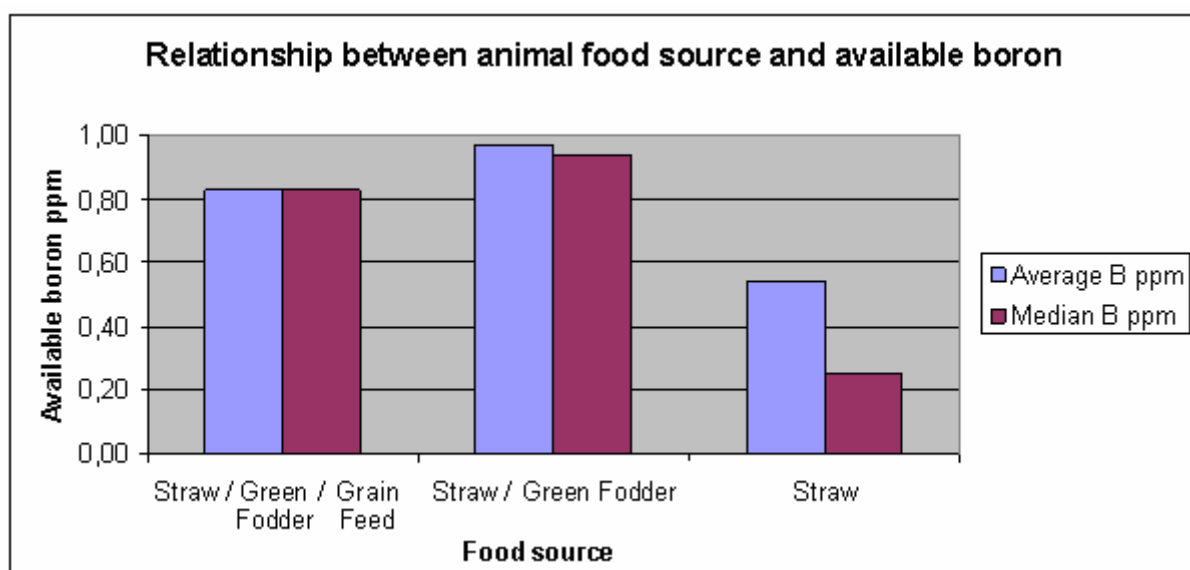


Figure 36: Histogram connecting animal food source and available boron

6. DISCUSSION

In this chapter I will discuss my hypotheses and whether they have been falsified or not. Inductive findings will also be examined.

6.1. HYPOTHESES

This chapter will be used to discuss my hypotheses. Focus is targeted against the data I have used to enlighten the hypotheses and whether I have been able to falsify them or not. Possible explanations will also be addressed.

6.1.1. Deficiency issues.

Hypothesis 1: “There are boron and zinc deficiencies in the field area.”

As mentioned earlier, are boron and zinc deficiencies relatively common in Nepalese soils. It is therefore natural to propose hypothesis 1. It is probably also my main hypothesis as all the others circulate around an assumption of a micronutrient deficiency.

I suppose my data for evaluating hypothesis 1 are relatively good. The validity of the data is definitely good; as I am sure I measure what I would like to measure. I could have included some extra soil factors to investigate the boron and zinc availability further, though. Examples are CEC for boron and organic carbon content for zinc.

The reliability is more questionable than the validity. I did not reach an adequate soil depth when I took all my samples and the number of sub-samples may have been a little few. As discussed in chapter 4.2., there has been a little misunderstanding with the lab as well. This case is sorted out, but it might be other issues that have not been revealed. Because of the good reputation of NESS, I did not expect trouble and this might have made me a bit inattentive to problems. Irrespective of these minor incidents I feel that the reliability of the data is good enough to enlighten hypothesis 1.

As expected, the hypothesis was not falsified. 32 percent of the samples were deficient in available boron and 29 percent were deficient in available zinc.

Hypothesis 2: “Khet is especially vulnerable to zinc deficiency, compared to bari.”

Hypothesis 2 is more complex than hypothesis 1 as it to some extent connects space to boron and zinc deficiencies.

Objections can be raised when I use my data to judge this hypothesis, as there are issues concerning the definitions of bari and khet. I ended up categorizing on the peasants terms, but it is not certain that this categorization is valid other places or by other people. Thus, I can only determine if hypothesis is falsified when khet and bari is defined the way it is in my study area. Using the results in a larger context can therefore be problematic. This is important if one is to compare different cases.

As with H1, H2 can not be falsified by my data. Figure 34 clearly show that available zinc levels generally are lower in khet than in bari. There might be, and probably are, several reasons for this, but FYM input should be addressed as a key factor. We have seen in chapter 5 that available zinc seems to be largely dependent on FYM input and that very little FYM is applied to khet compared to bari and vegetable fields. *It is therefore logical to think that available zinc is generally low in khet because the peasants give priority to bari and the vegetable fields, when it comes to FYM application.* This is reasonable as only rice is grown in khet and rice has relatively low nutrient requirements.

One should keep in mind that submergence of the paddy fields lowers the zinc availability considerable beyond the measured extent, as dry samples are obtained and analysed in this study. *Considering this fact, extremely low available zinc values are probably present in khet during the rice growing season.*

6.1.2. Farming system intensity.

Hypothesis 3: “The farming systems in my field area are of an intensive character.”

As discussed in chapter 3.2.2., is the intensity of a farming system a complex thing to measure. I have ended up with using the number of annual rotations as indicator. The fact that I have chosen to do it this way induces a lot of weaknesses to the validity of H3 and H4. A lot of data are ignored, for instance the types of plants that are cultivated. Different plants extract different amounts of nutrients from the soil and this is not taken into account when I have measured farming intensity.

Growing seasons have not been evaluated either. Different plant species often have different length of their growing seasons. Hypothetically, a field can therefore be occupied with plants as many days a year with one annual crop, as a field with two annual crops. Number of crops may therefore not be the most ideal measurement of farming intensity.

A last objection may be that it does not take intercropping into account. It is possible that intercropping induces an increased micronutrient drain, as more plants are present.

Looking at the arguments in the last section should tell us that the validity of H3, and consequently H4, is pretty poor. Still, I choose not to reject them, as they might say something interesting. After all, number of annual crops does measure farming intensity to some extent. The results should be treated with some care though.

In contrast to the validity, I assume the reliability of the farming intensity data to be good. I consider it not to be very likely that the peasants have misinterpreted me, or visa versa. They also commented that the rotation cycles were pretty permanent from year to year. The vegetable gardens have been left out of the investigations as there are no clear cropping frequencies. The seasonal vegetables are grown all year around, but with varying density. One might say that most vegetable gardens are cultivated in a more or less continuous way. This is obviously a weak spot in my statistics.

The average number of rotations in the dataset is 2,3. This can be regarded as a regular farming system when it comes to number of rotations, but as we saw in chapter 5.4.1. there are some clear divides in the data. These follow the land categories bari and khet. Figure 28 and 29 tells us that 88% of the bari fields have three annual rotations, while 84% of the khet

fields have only one rotation. Using number of rotations to measure farming intensity, this implies that an intensive farming system is exercised to the bari fields, while the opposite is the case for khet.

There is more than one reason for this divide, but a factor that can not be forgotten is FYM. As almost all FYM is used on bari, the farming intensity is also highest there. The plants on cultivated on bari is also generally more responsive to FYM than rice, which is the only crop on most khet fields.

Another factor is that bari are closer to the houses than khet and has a therefore smaller risk of being damaged by the river during the monsoon. It is therefore logical to invest the input in the bari. Labour is limiting for farming intensification, but no such data have been obtained in this study. Much focus is put on FYM. To produce FYM the peasants need food for their animals. This is often a problem, but having some grazing areas make it easier. Khet that is only cultivated during the monsoon is therefore very useful. Nutrients from khet are transported to bari through FYM obtained from the animals grazing on khet.

Summing up hypothesis 3, we can say that the farming system is of a partly intensive character. The divide goes between bari and khet.

Hypothesis 4: "Farming system intensity is likely to be the main controlling factor of zinc and boron deficiencies."

The logical interpretation of H4 is that a high farming intensity should lead to lower boron and zinc values than a low intensive farming intensity. The idea is that more nutrients are extracted from the soil when more plants are cultivated.

The correlation analyses in chapter 5.4. show that this is not the case. *For boron there is no correlation.* Consequently, boron values vary regardless of farming intensity (number of rotations). Available zinc has a 0,43 *positive* correlation with number of rotations, thus should a lot of rotations lead to higher zinc values if the relationship is true. This does not make much sense alone. It is therefore likely that the 0,43 correlation is caused by a extern factor. We know that there are generally low zinc values in khet and that the number of rotations in khet is low. The significant correlation between zinc and farming intensity is likely to be a result of this. Because the low input of FYM reduces zinc values in khet, it is very likely that FYM application is the extern factor.

I have not quantified the farming intensity of vegetable gardens, but cultivation of vegetables is generally regarded as very intensive, needing lots of fertilizer input in addition to labour. If H4 is to be correct, vegetable gardens should therefore have low boron and zinc values.

I did not come up with any such findings in my data; in fact, vegetable gardens tend to have adequate available zinc and boron levels.

Based on the findings in the last two paragraphs, we can say that farming system intensity (the way I define it) is *not* likely to be the main controlling factor of zinc and boron deficiencies. *H4 is therefore falsified.* It is impossible to say that there is no relation, though. It could very well be that FYM application is so important that it overshadows the effects of farming intensity.

6.1.3. Fertilizer use

Hypothesis 5: Moderate amounts of chemical fertilizers are applied.

Quantitative data on fertilizer use is gathered through interviewing, using the interview guide (Appendix I). The data on chemical fertilizer use should be solid as the definitions of the different types seem clear and the quantities generally are low. Because of these low amounts, every peasant knows exactly how much he uses. Despite poor knowledge of chemical fertilizers, the interest is huge and that made the data collection easy. I consider the data quality of the chemical fertilizer use to be very good.

The subject of chemical fertilizer quality will not be touched in this section, simply because I do not have any relevant data.

H5 uses the phrase “moderate amounts of chemical fertilizers”. As mentioned in chapter 3.3.4., the results should be evaluated in proportion to the average fertilizer use in Gandaki district in 1996. This was 25-50 kg per ha. A bit higher average should be expected when my research was carried out in 2005, mainly due to the liberation of the fertilizer market in 1997.

The mean chemical fertilizer use in my study area was 75 kg per ha. This is higher than the Gandaki average from 1995 and also probably a bit higher than the average for the district in

2005. *H5 could therefore be regarded as falsified. However, since I do not have any good data of Gandaki district from 2005, little weight can be put on this falsification.*

So why do peasants in Sedi Bagar apply relatively large amounts of chemical fertilizers? Pokhara and its markets are likely to be the main explanations. With the closest Agro-vet sited only a couple kilometres away, supplies of chemical fertilizers are very good. However, if the peasants in Sedi Bagar were only involved in subsistence agriculture, they would not have any money to buy fertilizers. This implies that the peasants sell some of their crops. In addition, one or a couple of the family members often work in Pokhara.

Tourism and the big urban market of Pokhara is therefore very important to fertilizer input, both because it creates jobs at hotels and other services, but also because restaurants and inhabitants buy vegetables from the local peasants. The money earned from these activities can be spent on chemical fertilizer, among other things.

The restricting factor of chemical fertilizer appliance I take for granted is lack of money, although negative perceptions probably also play a major part. Peasants in my study area claimed that the soil got “addicted” to Urea and DAP as well as cloddy and hard to till. My interpretation was that chemical fertilizer was perceived as a poor substitute for FYM, although it was recognized that it had some positive effects as well. This may partly explain why the level of chemical fertilizer input was not *higher* than 75 kg per ha.

Hypothesis 6: The chemical fertilizers contain mainly macro- and not micronutrients.

With a single exception of potassium, the only chemical fertilizers used in the study are DAP and Urea. H6 address the fertilizers used in the field area as macronutrient-based, without containing any micronutrients. The data I have gathered to inspect this hypothesis is from the two Agro-vets closest to Sedi Bagar. The staff was not of much help as they did not know more than what the labels on the bags told them. This was not much, but they did state that no micronutrients were included. *Based on these data it is not possible to falsify H6.* The hypothesis should be tested more critically though, as fertilizer quality is known to vary in Nepal. *The bottom line is that no chemical fertilizers that should contain micronutrients are applied in the study area.*

There are several reasons why micronutrients are not included in the most common fertilizers, but what I experienced is that the lack of knowledge is most important. It is obvious that if no one asks for micronutrient blended fertilizers, the producers and importers will not supply these goods to the markets or the buyers. Even if micronutrient blended fertilizers should find their way to the Agro-vets, the peasants will probably not buy them as they do not know the difference between the types. The knowledge of the staff at the Agro-vets is also a major issue. This will be discussed further in chapter 6.1.4.

Price is another factor to why micronutrients are not included in for instance DAP. Making these fertilizers is expensive and it is not likely that the peasants would buy the high-priced alternative when they do not know the difference. This leads us back to knowledge.

Finally there is the spatial aspect. We know that nutrient distributions vary greatly and it is therefore difficult to make general blended fertilizers. To be cost-efficient, the fields should ideally be sampled and the fertilizers should be based on the results.

Hypothesis 7: The micronutrient input is largely dependent upon FYM application.

H8 is a logical derivation of H6. If no micronutrients are added in form of chemical fertilizers, then all micronutrient input from fertilizers would come from FYM. There will always be some other input sources such as irrigation waters, precipitation and atmospheric depositions, but these are generally regarded as secondary and not of great importance. *Based on these assumptions and the fact that none of the reported chemical fertilizers contain micronutrients, H8 seems to stand rock solid.*

With regards to available zinc, the correlation analysis amplifies this impression, as the correlation coefficient between FYM and available zinc is 0,38. Boron does not show a similar relationship though.

As we have seen, the bari fields get almost all the FYM, and consequently almost all the inputted micronutrients. Ironically, a lot of the FYM is produced from animals grazing on the khet. As most khet fields in my field area are only cultivated in the monsoon period, buffaloes and other domestic animals are grazing the rest of the year. This leads to a nutrient flow from khet to bari as illustrated in figure 38

Obviously not all of the manure is transported back to the farm by the animals. Some is directly reintroduced to the khet, often called in-situ manuring. It should also be stated that the

grazing is only a part of the domestic animals food source. Stall-feeding of straw and other crop residues is perhaps the most important one. However, feeding the animals straw actually intensifies the nutrient flow shown in figure 37, as rice straw cultivated in khet are given as well as straw from the bari crops.

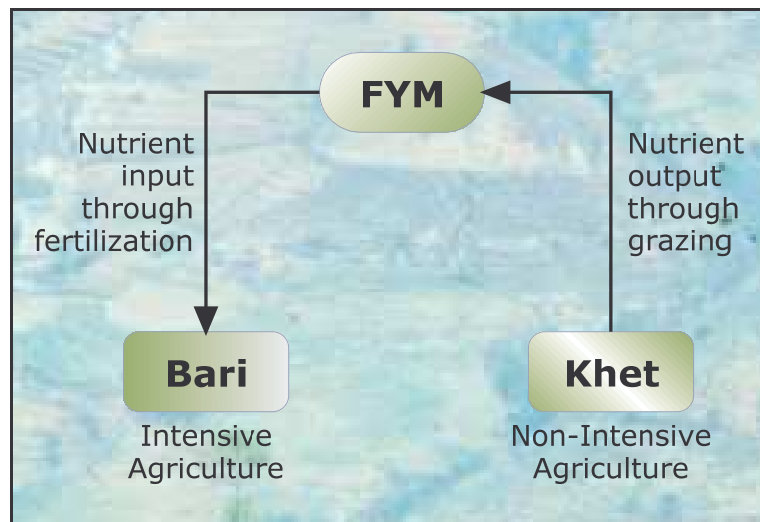


Figure 37: Nutrient flow in farming system. Nutrient loss from khet is gained in bari through FYM.

Figure 37 may partly explain why bari fields generally have higher zinc values than khet fields. The lacking relationship between boron and khet/bari questions this though. Why should only available zinc levels be affected by FYM application? One explanation might be that the FYM contain higher amounts of zinc than of boron. Unfortunately, I do not have any data on nutrient levels of FYM in the study area. This would have been very useful when determining the effect of FYM application.

Another likely explanation may be organic carbon content (OCC). It is clear that FYM increase organic matter content and consequently also OCC. Available zinc is known to increase with rising OCC, but available boron does not follow the same trend (Sillanpää 1982).

What I have found in this section is that relatively large amounts of chemical fertilizers are used, compared to the rest of the Gandaki district. This is connected to the proximity of Pokhara. The nutrient content of the applied chemical fertilizers are restricted to macronutrients, however. The major explanation is probably lacking knowledge, both of the salesmen and the peasants. Due to this, micronutrient input is limited to FYM. As basically

only bari receive FYM, khet is left without micronutrient input from fertilizers. In addition, agricultural outputs from khet are used to create FYM.

While available zinc seems to be very positively affected by FYM, available boron is not.

6.1.4. Fertilizer recommendations.

The two hypotheses discussed in this section regard the help and advices the peasants get when it comes to use fertilizers. They also try to enlighten whether using zinc and boron blended fertilizers are likely to help against zinc and boron deficiencies in my field area.

Hypothesis 8: The peasants in the study are not getting sufficient fertilizer recommendations.

The data used to investigate this hypothesis can be divided into a qualitative and a quantitative part. The quantitative data is collected with the interview guide (Appendix I). Here, all the peasants stated their main information source for fertilizer use. The qualitative data is obtained through conversations and unstructured interviews with the peasants and the staff at the two local Agro-vets. The objective was to uncover how much they knew about nutrient deficiencies in soils and plants, and how different fertilizers could help the situation.

Based on these data I found that the peasants in the study are not getting sufficient fertilizer recommendations and information. My explanation to this assertion is threefold.

First of all is the knowledge of the peasants low when it comes to deficiency issues and fertilizer use. The “power” hierarchy of fertilizers that seems widely accepted obviously has some weaknesses, as it does not take nutrient content of the fertilizers into account. But as most of the peasants does not know anything about nutrients (at least in a scientific sense), this is only natural. Still, the peasants need help if they are to overcome soil nutrient deficiency problems.

Second, the results of the structured interviews showed that all the peasants received their fertilizer recommendations from the local Agro-vet. No extension service or other research agencies seem present in the area. At least none of the interviewed peasants had any contact with such. Getting all the information and advices from Agro-vets may not be desirable as these are commercial enterprises, and commercial enterprises are known to focus on profit

sooner than the best of their customers. Selling and recommending low quality fertilizers may therefore actually be in the Agro-vets interest, at least in the short run!

The final explanation to why the peasants are not getting sufficient fertilizer recommendations has to do with lacking knowledge of the staff of the Agro-vets. My two visits to Agro-vets in Pokhara are not by far enough to say anything general about the knowledge base of employees at Agro-vets, but I can say what I experienced at these two places. The impression was not too good. They showed no evident knowledge of different nutrients and talked more or less in the same way as the peasants; “this fertilizer is good for fertility, but this one is better.” Thus, the “power”-concept from the peasants was applied in the store. However, in contrast to the peasants the store managers knew the nutrient contents of the different fertilizers. The meaning of this seemed somewhat unclear, though. When asked what they sold most of as well as recommended, the answer was Urea and DAP. The reason, according to one store manager, was that it is relatively cheap, but good. “Good” was explained as boosting the crops.

By investigating H8 I found that the peasants in my study only received fertilizing advices and information from where they bought the goods. The knowledge of the subject was low both at the Agro-vet and with the peasant.

Considering this and the fact that there are micronutrient deficiencies in the area, a working extension service with local soil/plant sampling and local fertilizer recommendations would be of great benefit to the peasants.

Hypothesis 9: Including boron and zinc in fertilizer recommendations are likely to be effective against deficiencies.

As we have seen in the last sections, the peasants in this study are recommended to apply DAP and Urea to their fields. At the same time we know that there are boron deficiencies in the study area. Now, the apparent question becomes; would adding zinc and boron to the fertilizer-diet help to get rid of these deficiencies? This could be done by applying single micronutrient fertilizers, such as borax and zinc sulphate, or applying boron and zinc blended

fertilizers. Answering the question firmly and with a good validity is impossible for me as I do not have the appropriate data. Some indications can be drawn, though.

Available soil zinc correlates well with FYM application in my dataset. This could be due to the levels of zinc in FYM, but other attributes of the FYM could also play a part making the zinc more available to plants. Since vast amounts of FYM usually are applied to bari, and not to khet, the latter is generally exposed to zinc deficiency. It is therefore logical to think that applying a zinc-containing fertilizer to khet could be effective against zinc deficiency. It may very well be that increased FYM application would be more fruitful, however.

Bari is more problematic and complex. With a lower percentage of the area being zinc deficient, zinc appliance becomes less relevant. In addition, a couple of high zinc values (for instance 13 ppm) were obtained from the bari fields. This induces the hazard of creating toxic zinc values.

Input of boron is connected with a lot of uncertainties. Available boron does not seem to respond to FYM in my dataset. It could be explained by low boron levels in FYM, but may also suggest that inputted boron does not become available to plants. This might be due to the soil properties mentioned in chapter 3.2.3. or that the soil does not attach enough of the boron. Also, the narrow difference between boron deficiency and toxicity makes boron input hard to handle. Appliance of boron may therefore have negative effects. This is verified by Sillanpää, who wrote; *“In several Nepalese trials signs of induced boron toxicity due to applied boron appear in spite of relatively low original boron status, calling for caution when correcting boron deficiency”* (Sillanpää 1990; 106). Especially rotations that include rice are problematic, as rice is sensitive to high boron concentrations (Andersen 2006). Wheat is on the other side of the boron sensitivity scale. As these two crops often are used in the same rotation system it is problematic to recommend boron application. One might end up with boosting the wheat crop and reducing the rice yield.

What seems clear is that appliance of zinc-containing fertilizers to khet fields are likely to be cost-effective. Applying the same fertilizers to bari might also be wise, but lower deficiency ratios and risk of toxicity probably makes this less efficient.

Although 31% of the samples in my study are boron deficient, adding boron seems to some extent as an uncertain business. The very feasible hazard of toxicity always lurks around the

corner when applying boron. Different crops have different toxicity limits and this makes boron application even more risky.

6.1.5. Spatial patterns.

To analyse spatial patterns, I have used point data from each sample site. These should for methodical reasons be distributed in a regular grid and all the samples should have a standardized distance between one another. This is not at all the case for my samples. The spatial analyse can therefore be questioned.

Hypothesis 10: There are spatial trends in the boron and zinc distributions.

Spatial autocorrelation is a good measurement of inter-spatial relationships between samples. When testing for spatial autocorrelation in chapter 5.3.2. using semivariograms, positive nor negative autocorrelation was proven. However, this was visual interpretations of graphs with *a lot* of dots. Although the human eye is really good at picking up patterns, we should not put too much weight on the interpretation of semivariograms.

Joint count statistics revealed the same result as the semivariograms regarding boron distribution; zero correlation. Consequently the boron values seem to vary randomly through my study area. Based on this, we can say that H10 is partly falsified. (Unless one thinks of the lacking pattern as a pattern itself.)

The reason for the zero autocorrelation is hard to figure based on my data, but naturally a lot of factors are playing a part. Geology and specially soil cover may very well be of importance, but the due to the poor resolution of the geology- and soil cover maps, checking this is impossible.

What we can say is that none of the data I have gathered seem to affect boron distributions notably.

One possible, but not very likely, exception is the correlation between animal food source and available boron as discussed in chapter 5.5.4. This is discussed further in chapter 6.2.3.

Available zinc, in contrast to available boron, showed some positive autocorrelation in the joins count statistics test. Deficient- and not deficient samples seemed to be more clustered than what a random distribution would suggest. If we examine figure 22 and 23, we see that

there are generally higher available zinc values in the centre of the map than at the outskirts. This seems like a pattern and H10 can therefore not be completely falsified.

So how can this pattern be explained? The concentration of samples with high zinc values is found in the centre and the north of the study area. This is also where the village is and accordingly also most of the bari fields. The khet fields are mainly located around and outside the village. Earlier, I have found that bari generally have higher available zinc values, while khet is the opposite, basically because of uneven FYM application. This relationship is what is reflected in the spatial distribution of zinc samples. *Bari fields in and around the village are high in zinc while khet fields outside the village are low.*

I mentioned in chapter 3.2. that some authors reckoned the whole of Nepal, as well as some neighbouring countries, to be part of a boron deficient region. Although “only” 32 percent of my samples were boron deficient, the hypothesis may actually fit with regards to my study area. This is due to the fact that none of the local factors I investigated affected available boron levels.

Carson (1992) claimed that mismanagement of the soil is the reason to boron and zinc deficiencies in Nepal. My case study shows that this is the case for zinc deficiency, as FYM application is usually lacking when zinc deficiency is present.

The spatial investigations revealed one more important thing. Boron- and especially zinc values vary a lot even over small distances. This is important to have in mind when discussing the possibilities of using blanket recommendations and general fertilizer advices.

6.2. OTHER FINDINGS

The discussion of the hypotheses in the previous chapter primarily takes care of the deductive findings in this thesis. There are a couple of subjects that have come along during the data collection and analysis as well. These principally inductive findings are discussed further here.

6.2.1. Effects of using animal bedding.

In the previous chapter we stated that zinc inputs as well as available zinc levels in soils seem to be very much subject to FYM appliance. The amount of available zinc is dependent upon the use of animal bedding as well. As found in chapter 5.5.3, fields that receive FYM with added animal bedding have *considerable* higher available zinc values than those fields receiving FYM without animal bedding. This connection was also indicated by the correlation analysis. The logic behind this relationship is based one the assumption saying that mixing urine soaked straw with FYM lead to a more rapid breakdown of organic matter. FYM application should therefore not be regarded as a general thing, it obviously vary greatly when it comes to its effect on soil properties.

6.2.2. Streams and rivers affecting available zinc?

Figure 26 shows clearly that zinc values tend to be low close to streams in my field area. There are reasons to believe that this is not a direct relationship, though. This comprehension is amplified by the findings saying that land type (probably due to FYM application) is the main influencer of available zinc levels. Put in other words, the high share of khet being distributed close to streams is the most likely explanation to the findings seen in figure 26. What seems proved is that zinc levels are not notably affected by erosion and sedimentation, as the steepest areas (far of the rivers) have highest zinc values and the flattest (close to river) have the lowest.

6.2.3. Leaves as animal food.

Animal food source is the only factor found that significantly correlates with available boron. As previously mentioned, one should be careful when discussing this relationship as the distribution of data values is highly uneven when it comes to animal food source. Only five peasants use nothing but straw as animal food.

Figure 36 illustrates the relationship clearly. The logic derivation is that green fodder (consisting of leaves from the nearby forest and grass from fields lying fallow) is contributing to higher available boron values than straw (mainly crop residues).

There is no reason to believe that the grass from the fallow fields is particularly high in boron. Leaves from the forest, on the other hand, are more interesting. One possibility might be that boron levels are generally higher in the forests than in the agricultural fields. If this is the case, input from the forests are likely to raise boron levels in the fields. Also, trees have considerably more extensive root nets and therefore the possibility to take up nutrients much deeper than agricultural crops. Unfortunately, I have no soil or plant samples from the forests surrounding Sedi Bagar. It is therefore impossible to say whether this leave-theory is anchored in reality or not.

However, the effects of using leaves contra straw as animal food source should be tested further. It is possible that this is a cost efficient way of coping with boron deficiencies without exposing the fields to boron toxicity. As the gathering of leaves demands labour rather than money, it is likely that the peasants are more interested in doing that than buying expensive borax or “vitamins”. Obviously, forests and especially fodder trees are needed. It is very possible that there is an unused potential in agro forestry oriented strategies, however.

7. CONCLUSIONS

In this thesis I have verified that there are zinc and boron deficiencies in Sedi Bagar. 32 percent of the obtained samples were deficient in available boron and 29 percent were deficient in available zinc. Only 6 out of 75 samples were deficient in both micronutrients. These figures are not dramatically high, but there are reasons for concern as less than half of the samples had sufficient boron *and* zinc levels.

The spatial and statistical analyses showed that the available zinc values to a large extent varied according to land category. Low available zinc values were often obtained in khet, while higher values generally were found in bari or vegetable fields. In addition is khet flooded during most of the cultivation period and this is likely to make zinc further unavailable to the crops. Zinc deficiency in khet must therefore be acknowledged as critical and the rice crops are likely to be severely affected.

A question naturally emerges; why are available zinc values lower in khet than in the other fields. This thesis suggests that the peasants' actions are the most likely cause. Khet fields in the field area do virtually not receive any micronutrient input in form chemical or organic fertilizers. Macronutrients are added in form of DAP and urea, but the micronutrients seem to be saved for the bari- and vegetable fields. There, vast amounts of FYM are applied, which is known to be a good source of zinc. Consequently, few bari fields are struggling with zinc deficiency. The rationale behind this practice is that bari generally have three rotations each year, while khet only have one. FYM is therefore applied to the most important fields.

It seems like the quality of the applied FYM vary, though. Considerable higher available zinc values are found in fields where FYM with added animal bedding are applied, than in fields that received FYM without animal bedding. This should imply that adding animal bedding to the manure stack is preferable, if one is to raise the levels of zinc and other nutrients.

One of the investigated hypotheses states that low available boron and zinc values are subject to high cropping intensity. The proposed logic is that intensive cultivation leads to nutrient mining and consequently low nutrient values in the soil. The hypothesis was rejected as no such relationship was found in the data. Quite on the contrary, it seemed like more annual crops raised available zinc levels in the respective fields. Available boron showed no such

trend, though. The amount of applied FYM is the most likely explanation to why high zinc values are found in the fields where most crops are cultivated annually. Thus, input of FYM seems more important than cropping intensity.

The spatial analysis did not show any indications of spatial autocorrelation in the boron dataset. In the same way, very few correlations were found during the statistical analysis. In fact, the only relationship which is worth mentioning is the one between available boron and animal food source. It indicates that animals consuming leaves produce FYM with higher boron content than those consuming crop residuals in form of straws. The hypothesis is based on few samples and direct measurement of the FYM has not been obtained. It should therefore be considered more as a suggestion for further studies, rather than a firm hypothesis derived from the data used in this thesis.

The different types of chemical fertilizers in the study area were restricted to DAP, urea and one single case of potassium. Thus, no micronutrients were added from chemical fertilizers. Considering there are boron and zinc deficiencies, one might wonder why no chemical fertilizers containing micronutrients are applied. This thesis has shown that lack of knowledge appears as the most prominent factor against use of such. The interviewed peasants do not operate with nutrients in a scientific sense, but more or less a “power concept”, rating the various inputs. This makes it hard to ask for the right fertilizers. Knowledge seems also to be a problem at the two local Agrovets where the peasants in Sedi Bagar buy their fertilizers. Another factor prohibiting the use of micronutrient fertilizers is the price. In addition, there seem to be a fundamental scepticism toward chemical fertilizer as opposed to the glorified FYM. The exception is in khet fields where virtually no FYM is added.

From a scientific point of view one might argue that use of micronutrient fertilizer is cost-effective. It is important, however, to remember that only some 55% of the fields in the study are deficient in boron, zinc or both. Some peasants might therefore lose money if they were to apply e.g. borax or zinc sulphate. Also, there is the distinct hazard of toxicity, especially with regards to boron. Micronutrient blended fertilizers along with continued FYM application might therefore be the best solution, minimizing risks and probably removing some deficiencies.

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Appendix I

Interview Guide

Question 5-11 only apply only to the sampled field.

Soil sample nr. _____ Khet Bari Vegetable garden

Coordinates: _____

1. Size of farm (ha): _____

2. Number and type of animals at the farm: _____.

3. Main animal food source: _____

4. Source of information regarding fertilizer: _____

5. Present crop: _____

6. Rotation cycle: _____

7. Use of animal bedding: Yes No

8. Amount of FYM: _____

9. Use of chemical fertilizer (type and amount):

10. Use of green manure: _____

11. When is FYM, green manure and chemical fertilizers applied?

Comments:

