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Preliminary Geochemical Top Soil Mapping in Urban Areas of Kalaw City, Southern Shan State

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Abstract

With the growth of the urban population, cities experience significant chemical impacts on air, water, soil, and living organisms due to industrial activities, heavy traffic, and waste disposal. This study aims to collect data and generate maps to understand the concentration and distribution of potentially harmful heavy metals in the top soils of Kalaw areas. Preliminary geochemical top soil mapping is a component of the urban geological mapping project in Kalaw areas. Soil sampling was conducted at a density of one representative sample per square kilometer, with a total of 41 soil samples collected from an area of 56 km^2. Top soil samples were analyzed using the Atomic Absorption Spectroscopy method to study the content of heavy metal elements. The average concentrations of elements are as follows: Pb (51.46 ppm), Zn (25.41 ppm), Cu (5.63 ppm), Cr (24.63 ppm), Ni (31.22 ppm), Fe (22429.27 ppm), and Mn (670.29 ppm). It was observed that the manganese (Mn) content slightly exceeded the threshold values by the Food and Agriculture Organization (FAO), while the remaining elements were below the threshold values. Preliminary Geochemical maps were generated using ArcGIS 10.8 software, enabling the identification of locations where elements are present and their potential sources. This study represents the first preliminary systematic documentation of toxic heavy metal concentrations in the soils at surrounding Kalaw City, and it will facilitate informed decision-making regarding soil quality in the formulation of future urban planning initiatives.

Keywords: *Atomic Absorption Spectroscopy (AAS), ArcGIS 10.8, Geochemical map, Soil sampling, Heavy metals, Urban geological mapping*

ရှမ်းပြည်နယ် (တောင်ပိုင်း) ကလောမြို့၊ ပဏာမအဆင့်ဘူမိဓာတုဗေဒဆိုင်ရာ အပေါ်ယံမြေဆီလွှာ မြေပုံရေးဆွဲခြင်း

ကျော်ကျော်ဦး၊ လက်ထောက်ဘူမိဗေဒအရာရှိ
ဘူမိဗေဒလေ့လာရေးနှင့် ဓာတ်သတ္တုရှာဖွေရေးဦးစီးဌာန

စာတမ်းအကျဉ်း

မြို့ပြလူဦးရေ တိုးပွားလာမှုနှင့်အတူ မြို့ကြီးများတွင် စက်မှုလုပ်ငန်းများ၊ ယာဉ်ကြောထူထပ်မှု၊ စွန့်ပစ်ပစ္စည်းများကြောင့် လေထု၊ ရေထု၊ မြေထုနှင့် သက်ရှိများအပေါ် ကြီးမားသော ဓာတုဗေဒဆိုင်ရာသက်ရောက်မှုများရှိပါသည်။ ဤလေ့လာမှု၏ ရည်ရွယ်ချက်မှာ ကလောဒေသရှိ အပေါ်ယံမြေဆီလွှာနမူနာများကိုရယူ၍ ၎င်းတွင် ပါဝင်နေသော အန္တရာယ်ဖြစ်စေနိုင်သည့် အလေးစီး သတ္တုဒြပ်စင်များ၏ ပမာဏနှင့် ပျံ့နှံ့မှုကို သိရှိ၍ မြေပုံများ ရေးဆွဲရန်ဖြစ်ပါသည်။ ပဏာမအဆင့် ဘူမိဓာတုဗေဒဆိုင်ရာ အပေါ်ယံ မြေဆီလွှာမြေပုံ ရေးဆွဲခြင်းသည် ကလောမြို့နှင့် ဝန်းကျင်ဒေသမြို့ပြအကျိုးပြု ဘူမိဗေဒမြေပုံ ရေးဆွဲရေးလုပ်ငန်း၏ အစိတ်အပိုင်းတစ်ခုလည်းဖြစ်ပါသည်။ နမူနာယူခြင်းကို ၁ စတုရန်း ကီလိုမီတာ ပတ်လည်လျှင် ကိုယ်စားပြု နမူနာတစ်ထုပ်နှုန်းဖြင့် စုစုပေါင်းဧရိယာ ၅၆ စတုရန်းကီလိုမီတာအတွင်း မြေဆီလွှာနမူနာ ၄၁ထုပ် ရယူခဲ့ပါသည်။ မြေဆီလွှာနမူနာများကို Atomic Absorption Spectroscopy နည်းစဉ်ဖြင့် ဓာတ်ခွဲ၍ အလေးစီးသတ္တုဒြပ်စင်များ ပါဝင်မှုကို လေ့လာ ခဲ့ရာ Pb (51.46 ppm), Zn (25.41 ppm), Cu (5.63 ppm), Cr (24.63 ppm), Ni (31.22 ppm), Fe (22429.27 ppm)နှင့် Mn(670.29 ppm)တို့၏ ပျမ်းမျှပါဝင်မှုသည် ကုလသမဂ္ဂစားနပ်ရိက္ခာနှင့် စိုက်ပျိုးရေးအဖွဲ့ (Food and Agriculture Organization) ၏ သတ်မှတ်စံနှုန်းများထက် မန်းဂနိစ်ဒြပ်စင်သည် အနည်းငယ်များနေ သည်မှအပ ကျန်ဒြပ်စင်များသည် သတ်မှတ်စံနှုန်းများထက် နည်းပါးသည်ကို တွေ့ရှိရပါသည်။ ဘူမိဓာတုဗေဒ ဆိုင်ရာမြေပုံများကို ArcGIS 10.8 software အသုံးပြု၍ ရေးဆွဲခဲ့ပြီး ဒြပ်စင်များပါဝင်သည့် နေရာနှင့် ဒြပ်စင်များ၏ ဖြစ်နိုင်ခြေရှိသော ဇစ်မြစ်များကို ခွဲခြားသိရှိနိုင်ခဲ့ရာ ဤလေ့လာမှုသည် ကလောမြို့ ဝန်းကျင်ရှိ မြေဆီလွှာများတွင် အဆိပ်သင့်စေနိုင်သည့် အလေးစီးသတ္တုဒြပ်စင်များပါဝင်မှုကို ပထမဆုံးအကြိမ် ပဏာမအဆင့် စနစ်တကျ မှတ်တမ်းတင်ထားပြီး အနာဂတ်၌ မြို့ပြစီမံကိန်းများ ရေးဆွဲရာတွင် မြေဆီလွှာအရည်အသွေး ဆိုင်ရာဆုံးဖြတ်ချက်များချမှတ်နိုင်မည်ဖြစ်ပါသည်။

Preliminary Geochemical Top Soil Mapping in Urban Areas of Kalaw City, Southern Shan State

1. Introduction

The rapid development of urban areas alters the chemical properties of the soil and enhances the accumulation of toxic metals. Urban top soils are a place where contaminants from various anthropogenic sources accumulate, including household waste, vehicle emissions, particles from brakes and tires, industrial waste, agricultural fertilizers and pesticides, as well as construction activities. These sources release heavy metals into the environment, which subsequently settle and remain on the topsoil. The top layer of urban soils tends to accumulate contaminants more readily than deeper soil layers, and therefore, it is crucial to monitor soil quality. Preliminary geochemical top soil mapping was conducted as part of the urban geological mapping project in Kalaw Township. Soil contamination with heavy metals is a challenging concern that threatens plants, animals, and human health. These contaminants can accumulate in the human body through direct transfer from air, water, or soil, as well as through the food chain via plant uptake (Aelion et al., 2008). Heavy metals are naturally occurring metallic elements with high density, typically having a density > 5 g/cm^3 and an atomic number > 20 (Stephen J. Hawkes, 1997). Example of heavy metals include mercury (Hg), nickel (Ni), cadmium ((Cd), arsenic (As), chromium (Cr), Zinc (Zn), lead (Pb) and manganese (Mn). Although these metals can be found in topsoil, they can only be classified as posing a toxic risk if their concentrations exceed the permissible limits set by international organizations. In such cases, the presence of heavy metals may pose ecological or health risks, and the assessed area is deemed polluted.

Analysis of 41 surface soil samples collected from Kalaw and its surrounding areas was conducted using Atomic Absorption Spectroscopy (AAS). The results revealed that the concentrations of hazardous elements harmful to humans and animals namely mercury (Hg), cadmium (Cd), arsenic (As), barium (Ba), molybdenum (Mo), and antimony (Sb) were significantly lower than the standard guidelines established by the Food and Agriculture Organization, falling below the detection limit (Lower Than Detection Limit - LDL). Furthermore, the mean concentrations of lead (Pb), chromium (Cr), nickel (Ni), zinc (Zn), iron (Fe), and copper (Cu) were found to be below the FAO standards. However, the mean concentration of manganese (Mn) was slightly above the established standard guideline.

2. Objectives

This study aims to measure the concentrations of potentially hazardous heavy metals in the surface soils of Kalaw and its surrounding areas, to identify their spatial distribution and sources, to assess the level of soil contamination by comparing the findings with the threshold values established by international organizations such as the FAO (UN Food and Agriculture Organization), and to produce preliminary geochemical maps of Kalaw, a city with a population of over 19,000 (2025, GAD), using a Geographic Information System (GIS).

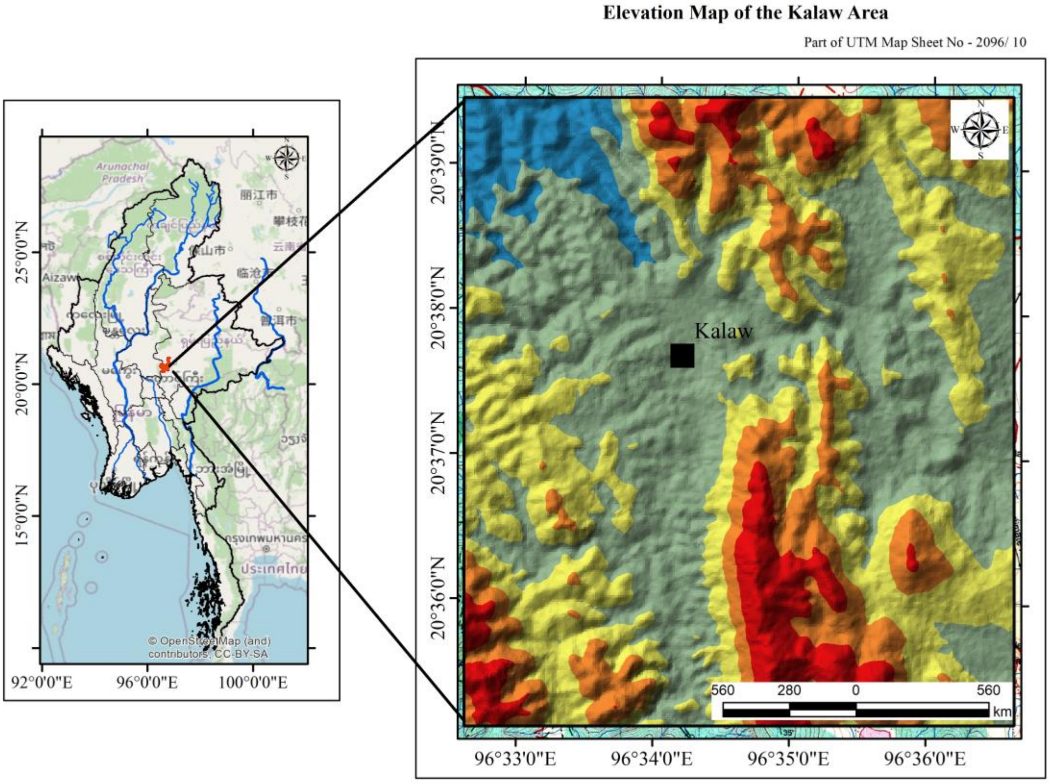

Figure 1. Location map of the study area

3. Materials and Methods

3.1 Study area

Kalaw is located in the southern part of Shan State, at an elevation of approximately 1,315 meters above sea level. It is bounded to the east by Aungban and to the west by Mandalay Region. The study area lies within a portion of UTM map sheet number 2096-10. It is situated between easting 244,000 m E and 251,000 m E, and northing 2,278,000 m N and 2,286,000 m N, covering an area of 56 square kilometers (approximately 13,837.9 acres) (Figure - 1).

3.2. Geomorphology and Geology

Kalaw is situated along the western margin of the Shan Plateau, an area abundant with mountain ridges, ravines, and valleys. Geomorphologically and tectonically, Myanmar is divided into four major provinces, and Kalaw is situated within the Shan-Tanintharyi Block. In the Kalaw area and its surrounding regions, various geological formations of different ages are exposed. Rock units from the Paleozoic, Mesozoic, and Cenozoic eras can be observed. The rock types found include limestone, dolostone, sandstone, shale, quartzose sandstone, conglomerate and breccia, as well as red-colored siltstone.

3.3. Methodology

Topsoil sampling was conducted at 41 locations within a predefined 1 km × 1 km grid covering the 56 km² study area, at a depth of 0–10 cm (Figure - 2 and 3). At each sampling site, debris and surface vegetation were removed, and samples were collected in sealable plastic bags. The samples were air-dried at room temperature (not exceeding 50°C) and ground into fine powder. After sieving, representative samples were obtained using the coning and quartering method. A minimum of 200 grams was weighed using a digital balance before being sent to the laboratory. Subsequently, the concentrations of heavy metals including mercury (Hg), cadmium (Cd), lead (Pb), chromium (Cr), arsenic (As), nickel (Ni), zinc (Zn), manganese (Mn), molybdenum (Mo), barium (Ba), antimony (Sb), and copper (Cu) were analyzed using Atomic Absorption Spectroscopy (AAS). All analytical procedures were carried out at the chemical laboratory of the Department of Geological Survey and Mineral Exploration. Subsequently, the assay results were statistically analyzed by calculating the mean, minimum, maximum, median, and standard deviation values. The data were then compared with the standard guidelines established by the Food and Agriculture Organization (FAO). Additionally, the spatial distribution patterns of potentially hazardous heavy metals were studied using a Geographic Information System (GIS) within the ArcMap platform.

4. Results and Discussion

In the study area, significant differences in the levels of heavy metals were found according to urban land use types. The descriptive statistics of heavy metal concentrations are presented in Table 1. Average concentrations reported in the literature by the Food and Agriculture Organization (FAO) are also provided for comparison**.**

Table 1 - Statistical summary of heavy metal concentrations (ppm) in top soils from Kalaw extracted by Atomic Absorption Spectroscopy (AAS). An average concentration for the Food and Agriculture Organization (FAO) and some countries is also given for comparison purposes.

	Pb	**Cr**	**Ni**	**Zn**	**Mn**	**Fe**	**Cu**
Mean	51.46	25	31.22	25.41	670.29	22429.27	5.63
Minimum	16	1	10	4	54	10,200	1
Maximum	120	236	106	68	2100	57,900	32
Median	44	10	28	24	436	20,000	2
Standard Deviation	24.72	42.40	18.44	14.30	544.89	10,701.72	7.25
Netherlands (Decree No. 609, 2008)	85	100	35	140	NA	NA	36
India (Kumari Sonu, 2019)	500	NA	NA	600	NA	NA	270
China (GB 15618-2018)	120	200	100	250	NA	NA	100
FAO (Chemicals Act,2004)	300	300	150	500	500	50,000	150

4.1 Distribution of Lead (Pb)

The distribution of lead (Pb) concentrations in the top soils of Kalaw and its surrounding areas ranges from 16 ppm to 120 ppm. The mean concentration is 51.46 ppm, with a standard deviation of 24.72 ppm. The threshold value established by the FAO is 300 ppm. Among the 41 soil samples collected during the field survey, no locations were found to exceed the FAO standard of 300 ppm (Figure - 2) (Figure - 9).

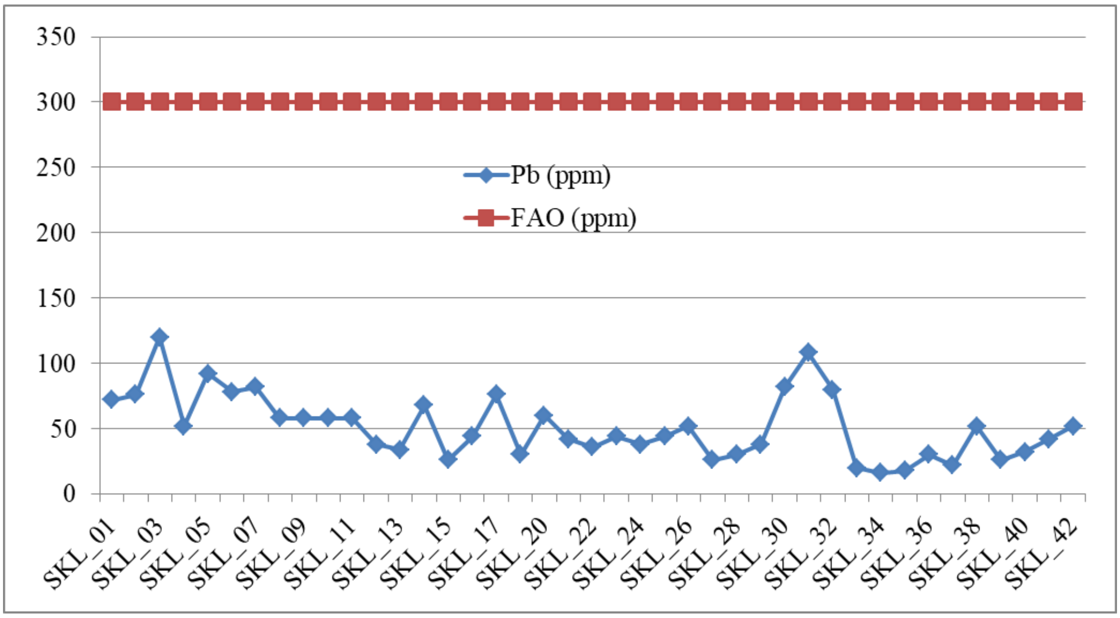

Figure 2- Frequency Distribution Histogram of Lead (Pb) in top soil of the Kalaw area

4.2 Distribution of Chromium (Cr)

The distribution of chromium (Cr) concentrations in the top soils of Kalaw and its surrounding areas ranges from 1 ppm to 236 ppm. The mean concentration is 25 ppm, with a standard deviation of 42.40 ppm. The threshold value established by the FAO is 300 ppm. Among the 41 soil samples collected during the field survey, no locations were found to exceed the FAO standard of 300 ppm (Figure - 3) (Figure - 10).

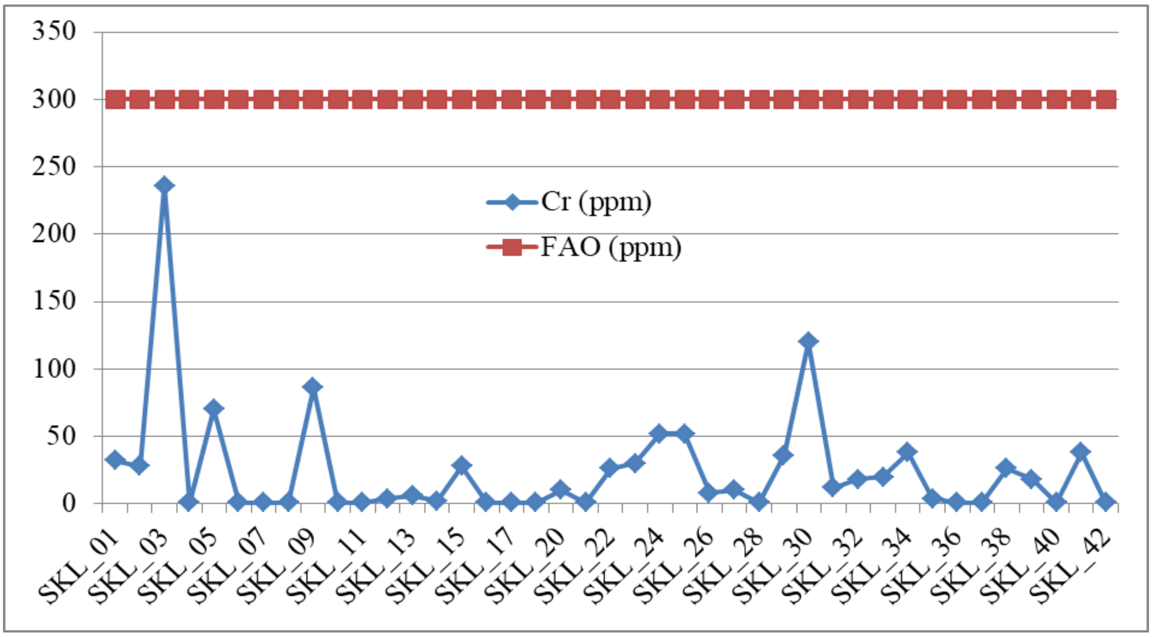

Figure 3- Frequency Distribution Histogram of Chromium (Cr) in top soil of the Kalaw area

4.3 Distribution of Nickel (Ni)

The distribution of nickel (Ni) concentrations in the top soils of Kalaw and its surrounding areas ranges from 10 ppm to 106 ppm. The mean concentration is 31.22 ppm, with a standard deviation of 18.44 ppm. The threshold value established by the FAO is 150 ppm. Among the 41 soil samples collected during the field survey, no locations were found to exceed the FAO standard of 150 ppm (Figure - 4) (Figure - 11).

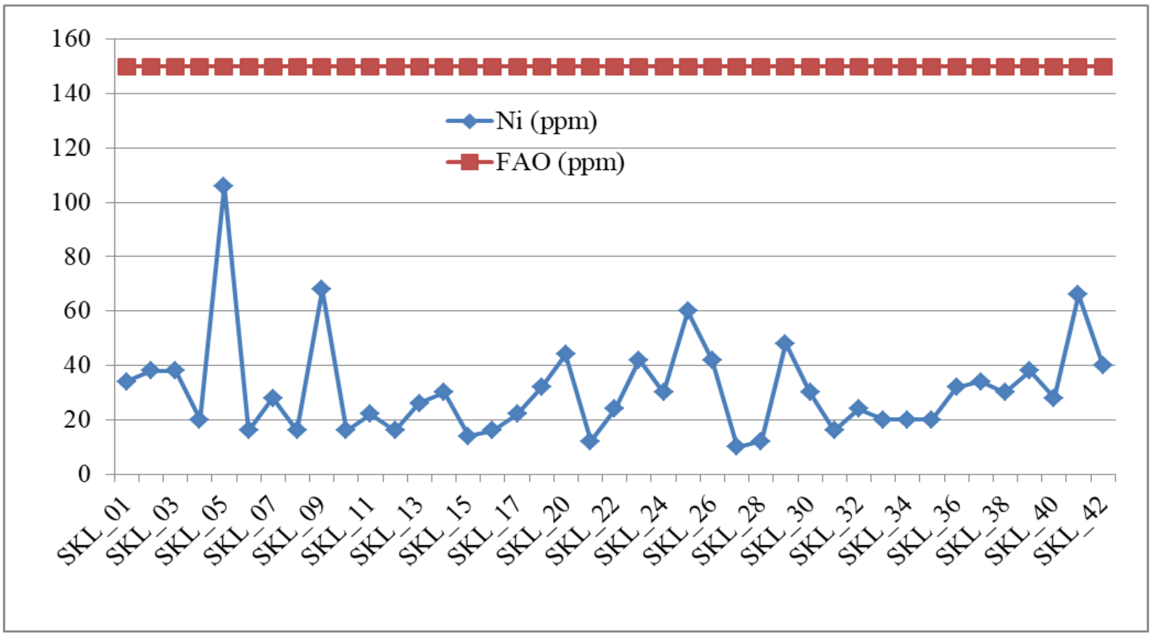

Figure 4 - Frequency Distribution Histogram of Nickel (Ni) in top soil of the Kalaw area

4.4. Distribution of Zinc (Zn)

The distribution of zinc (Zn) concentrations in the top soils of Kalaw and its surrounding areas ranges from 4 ppm to 68 ppm. The mean concentration is 25.41 ppm, with a standard deviation of 14.30 ppm. The threshold value established by the FAO is 500 ppm. Among the 41 soil samples collected during the field survey, no locations were found to exceed the FAO standard of 500 ppm (Figure - 5) (Figure - 12).

4.5. Distribution of Manganese (Mn)

The distribution of manganese (Mn) concentrations in the top soils of Kalaw and its surrounding areas ranges from 54 ppm to 2100 ppm. The mean concentration is 670.29 ppm, with a standard deviation of 544.89 ppm. The threshold value established by the FAO is 500 ppm. Among the 41 soil samples collected during the field survey, 19 locations were found to exceed the FAO standard of 500 ppm (Figure - 6) (Figure - 13).

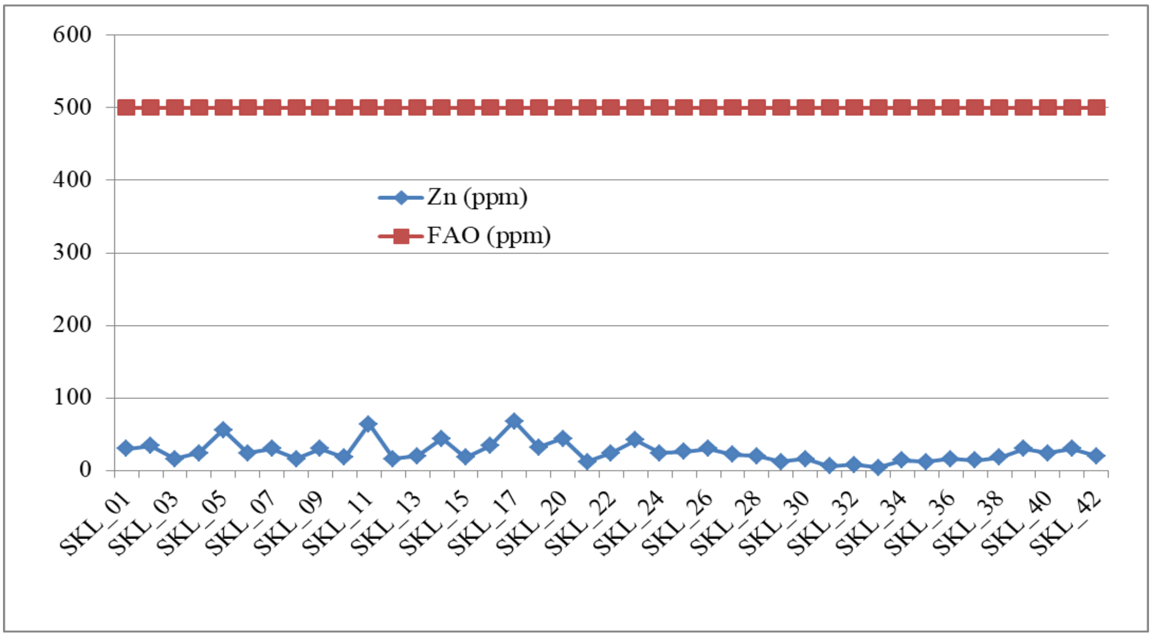

Figure 5 - Frequency Distribution Histogram of Zinc (Zn) in top soil of the Kalaw area

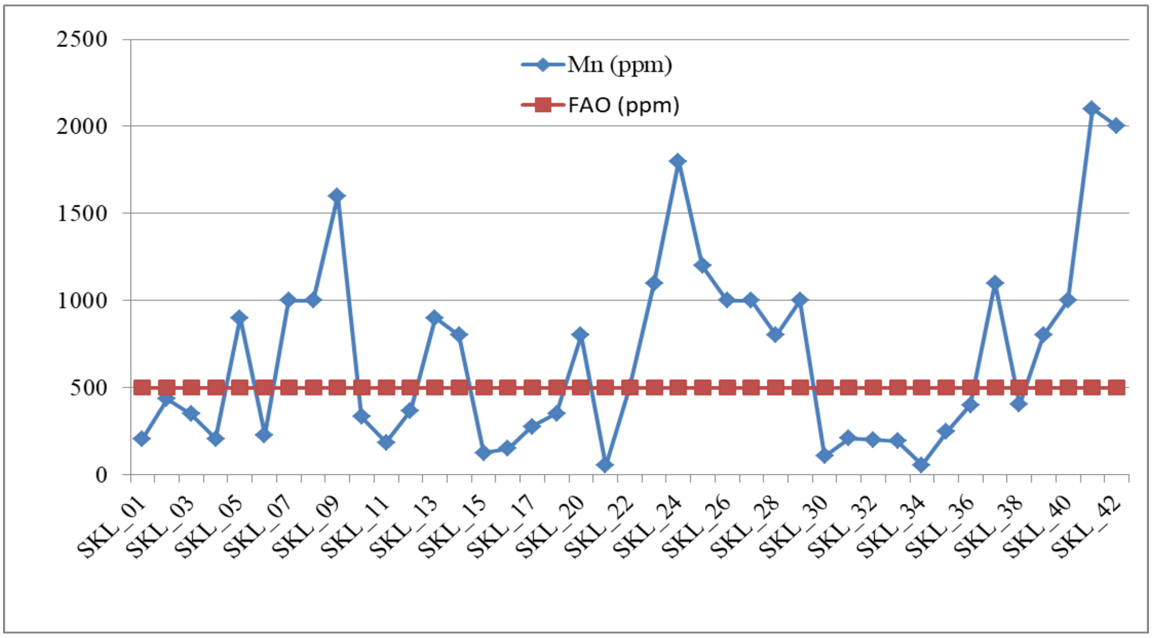

Figure 6 - Frequency Distribution Histogram of Manganese (Mn) in top soil of the Kalaw area

4.6. Distribution of Iron (Fe)

The distribution of iron (Fe) concentrations in the top soils of Kalaw and its surrounding areas ranges from 10,200 ppm to 57,900 ppm. The mean concentration is 22429.27 ppm, with a standard deviation of 10,701.72 ppm. The threshold value established by the FAO is 50,000 ppm. Among the 41 soil samples collected during the field survey, 1 location was found to exceed the FAO standard of 50,000 ppm (Figure - 7) (Figure - 14).

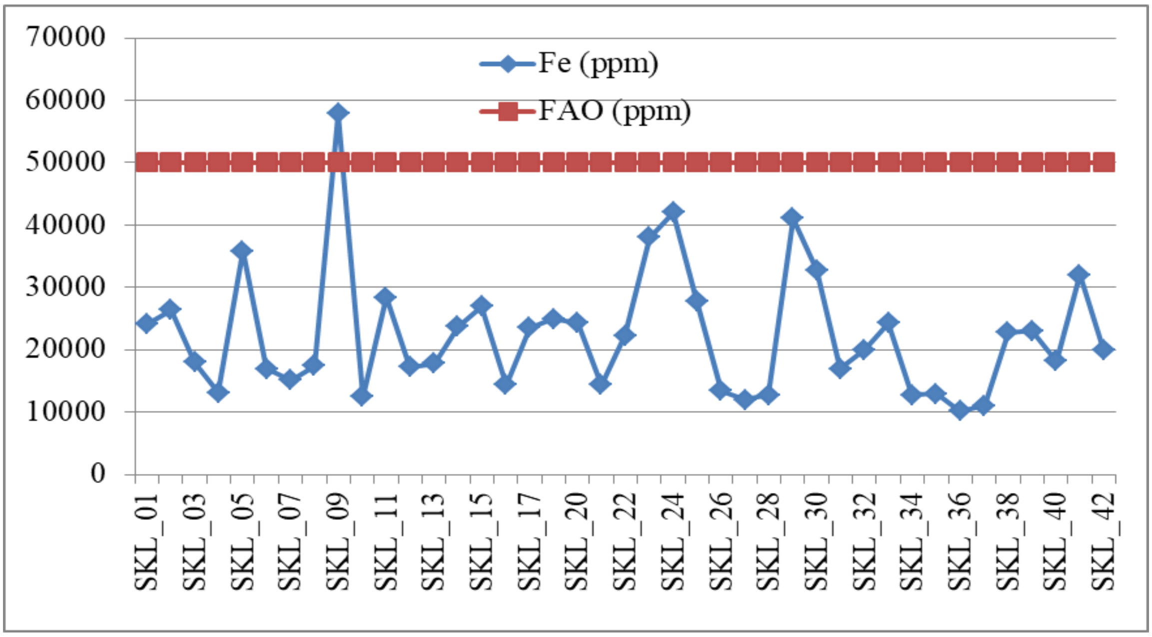

Figure 7 - Frequency Distribution Histogram of Iron (Fe) in top soil of the Kalaw area

4.7 Distribution of Copper (Cu)

The distribution of copper (Cu) concentrations in the top soils of Kalaw and its surrounding areas ranges from 1 ppm to 32 ppm. The mean concentration is 5.63 ppm, with a standard deviation of 7.25 ppm. The threshold value established by the FAO is 150 ppm. Among the 41 soil samples collected during the field survey, no locations were found to exceed the FAO standard of 150 ppm (Figure - 8) (Figure - 15).

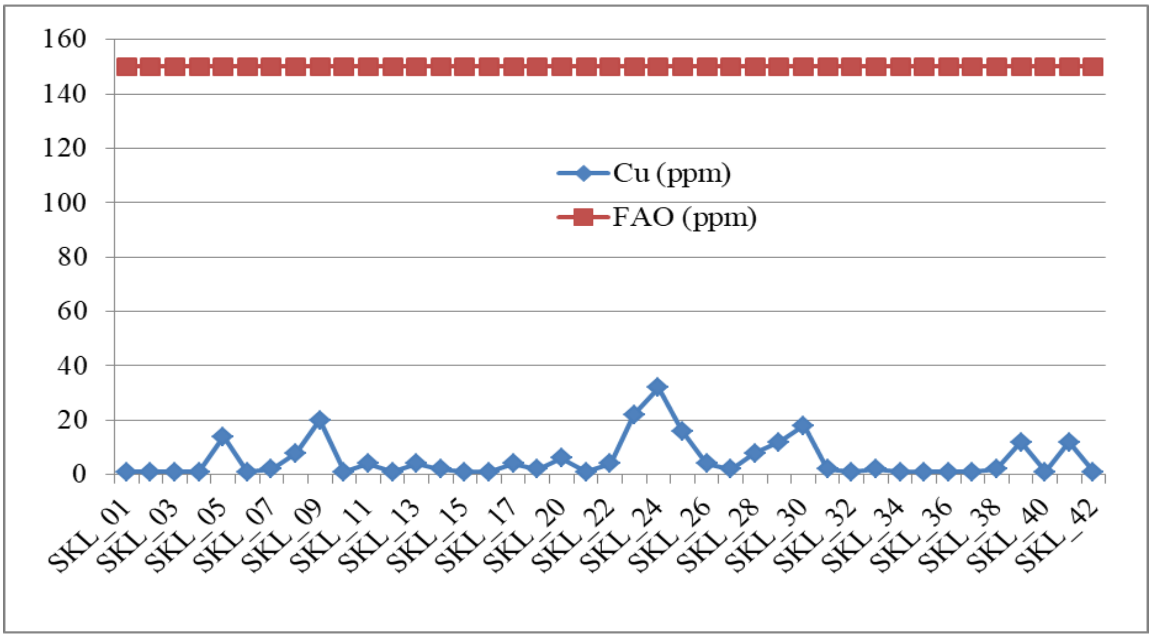

Figure 8 - Frequency Distribution Histogram of Copper (Cu) in top soil of the Kalaw area

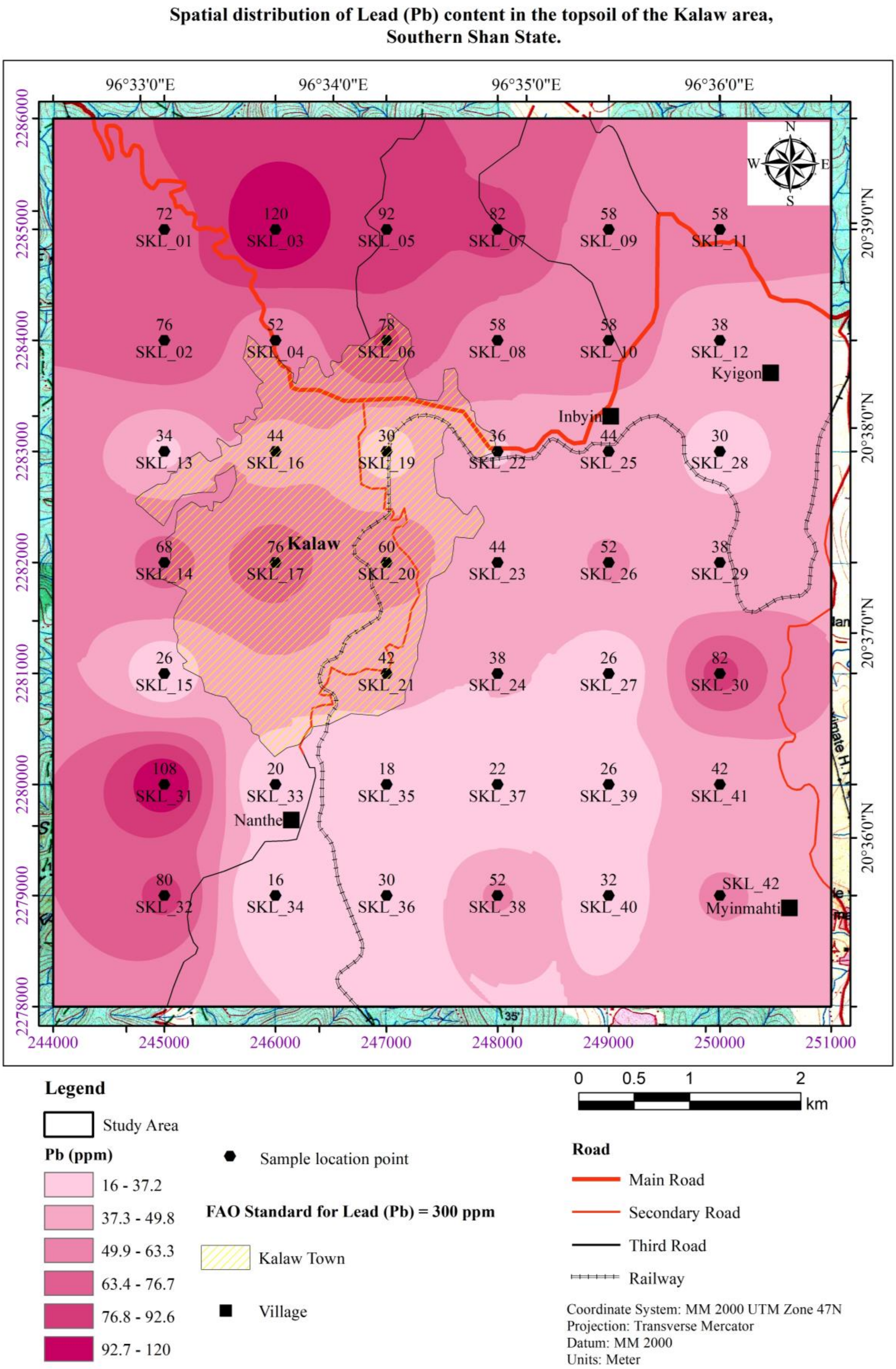

Figure 9. Spatial distribution of Lead (Pb) content in the topsoil of the Kalaw area, Southern Shan State.

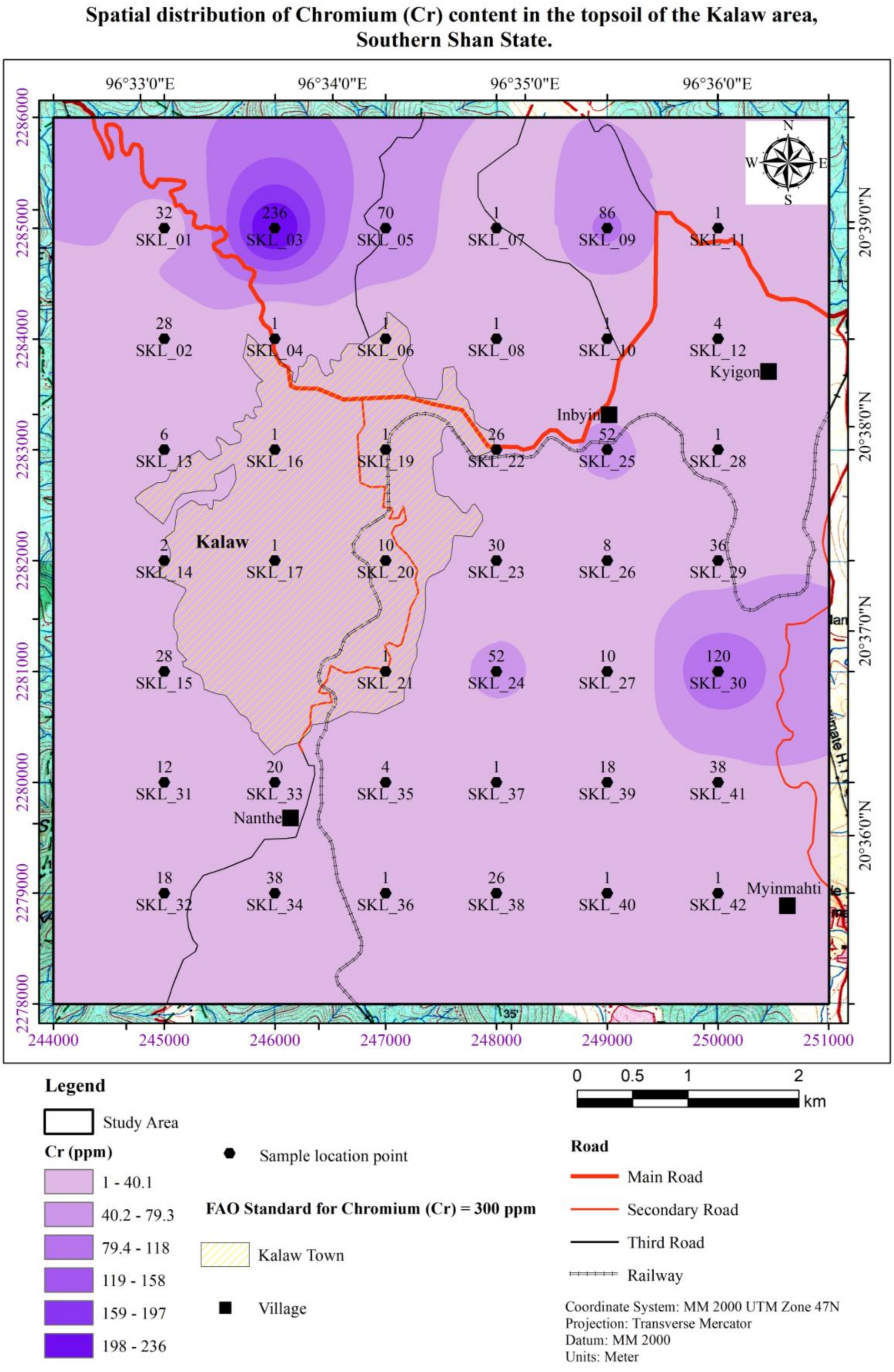

Figure 10. Spatial distribution of Chromium (Cr) content in the topsoil of the Kalaw area,

Southern Shan State.

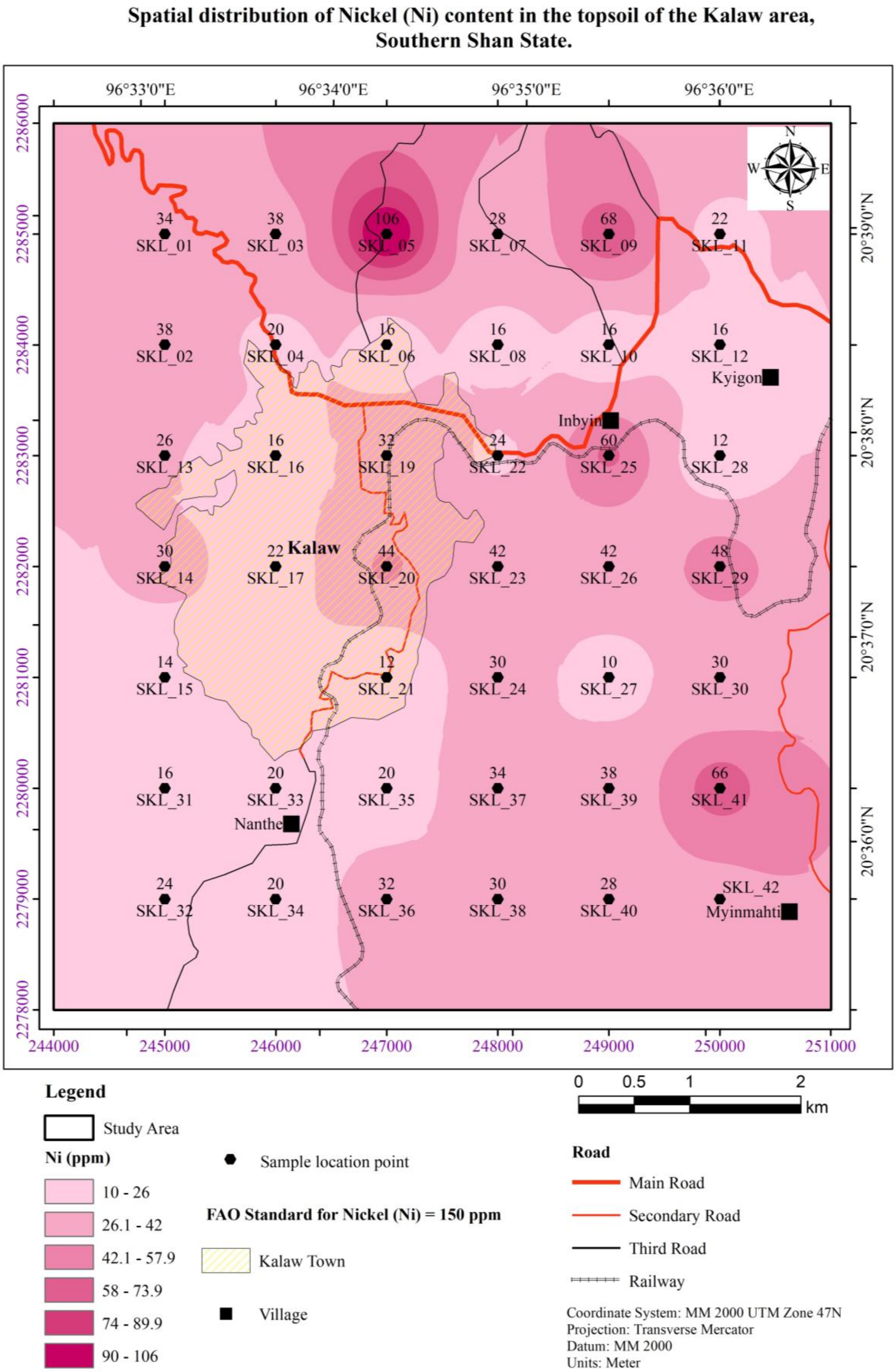

Figure 11. Spatial distribution of Nickel (Ni) content in the topsoil of the Kalaw area,

Southern Shan State

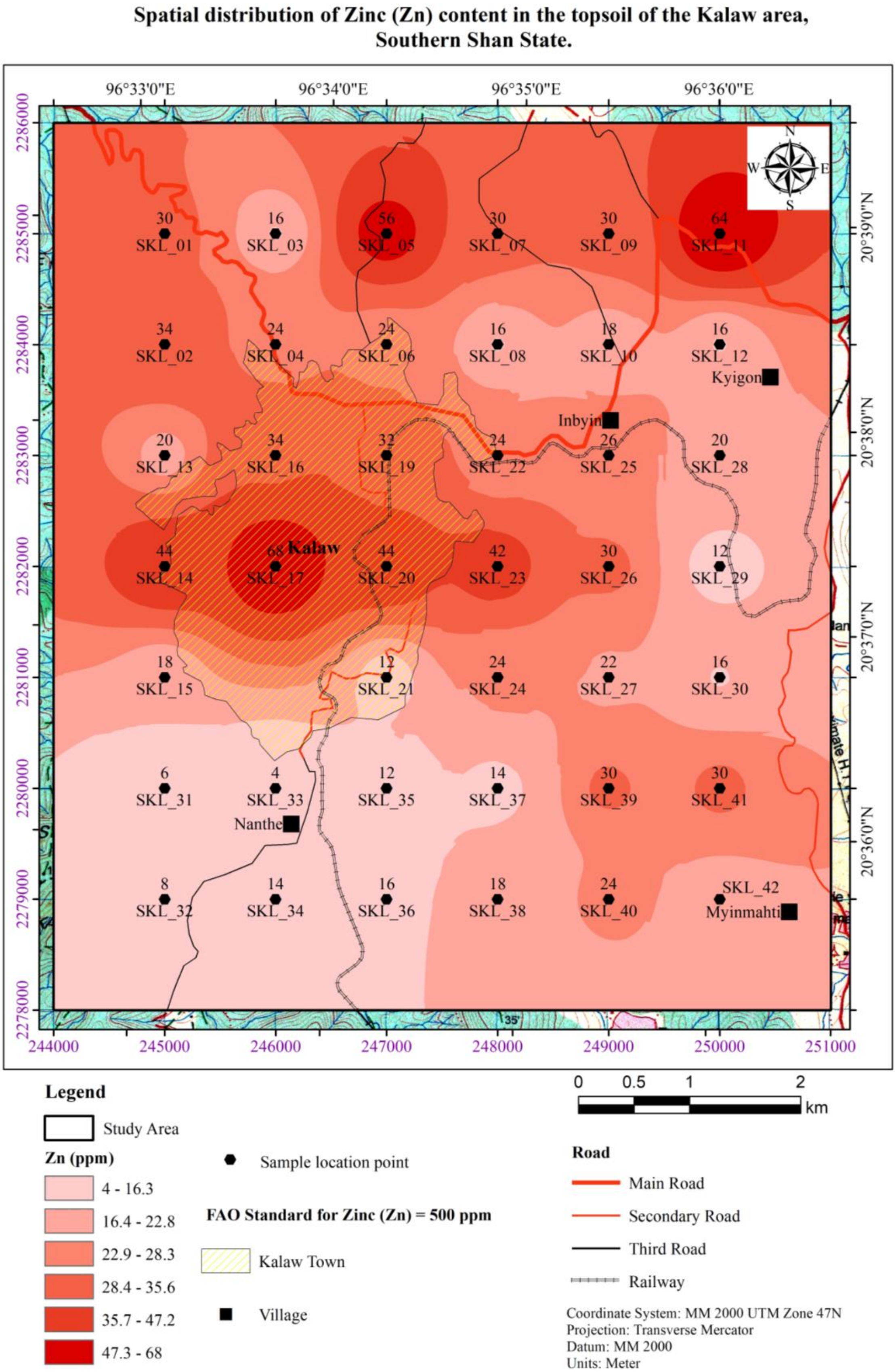

Figure 12. Spatial distribution of Znic (Zn) content in the topsoil of the Kalaw area,

Southern Shan State

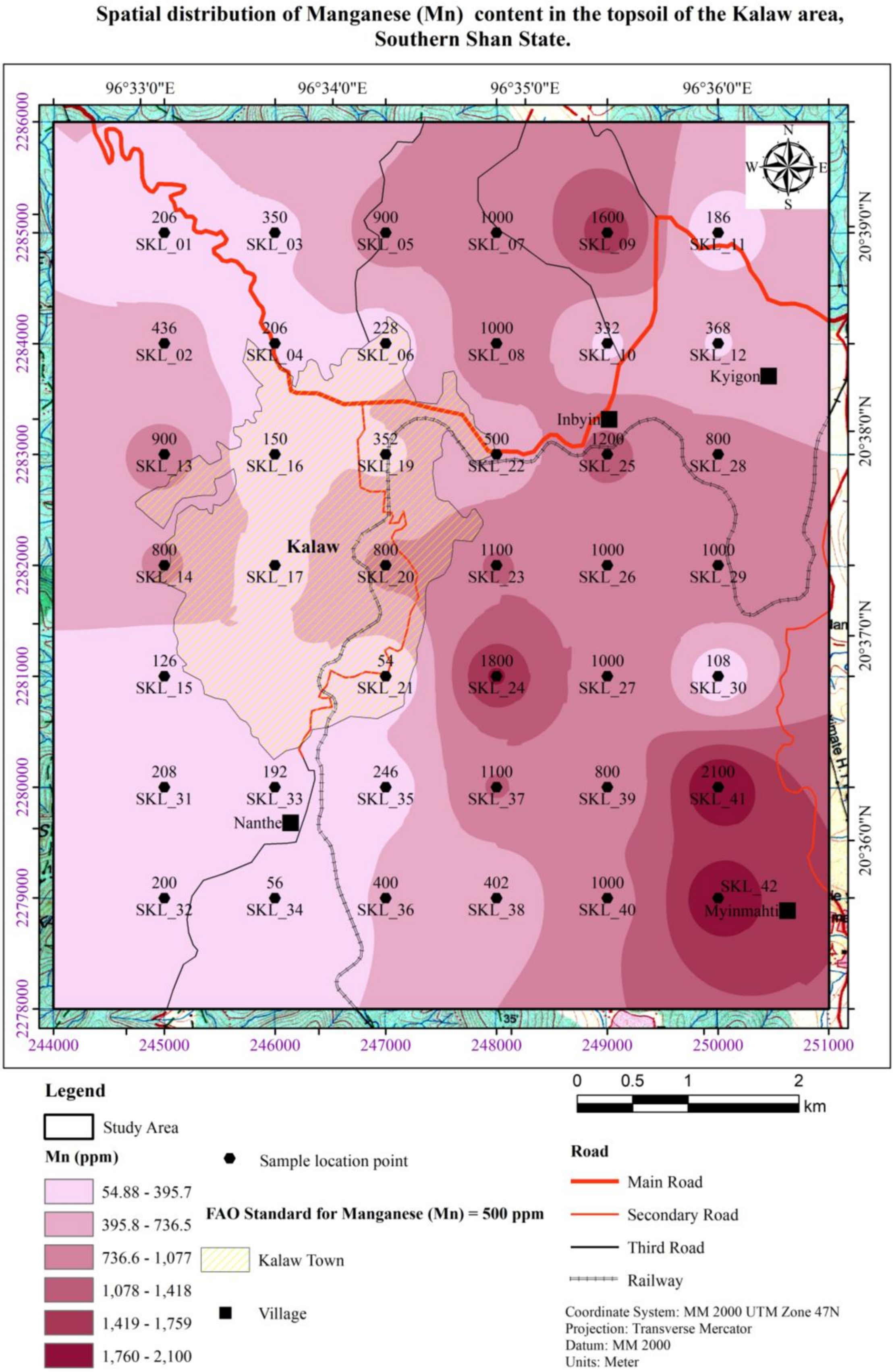

Figure 13. Spatial distribution of Manganese (Mn) content in the topsoil of the Kalaw area,

Southern Shan State.

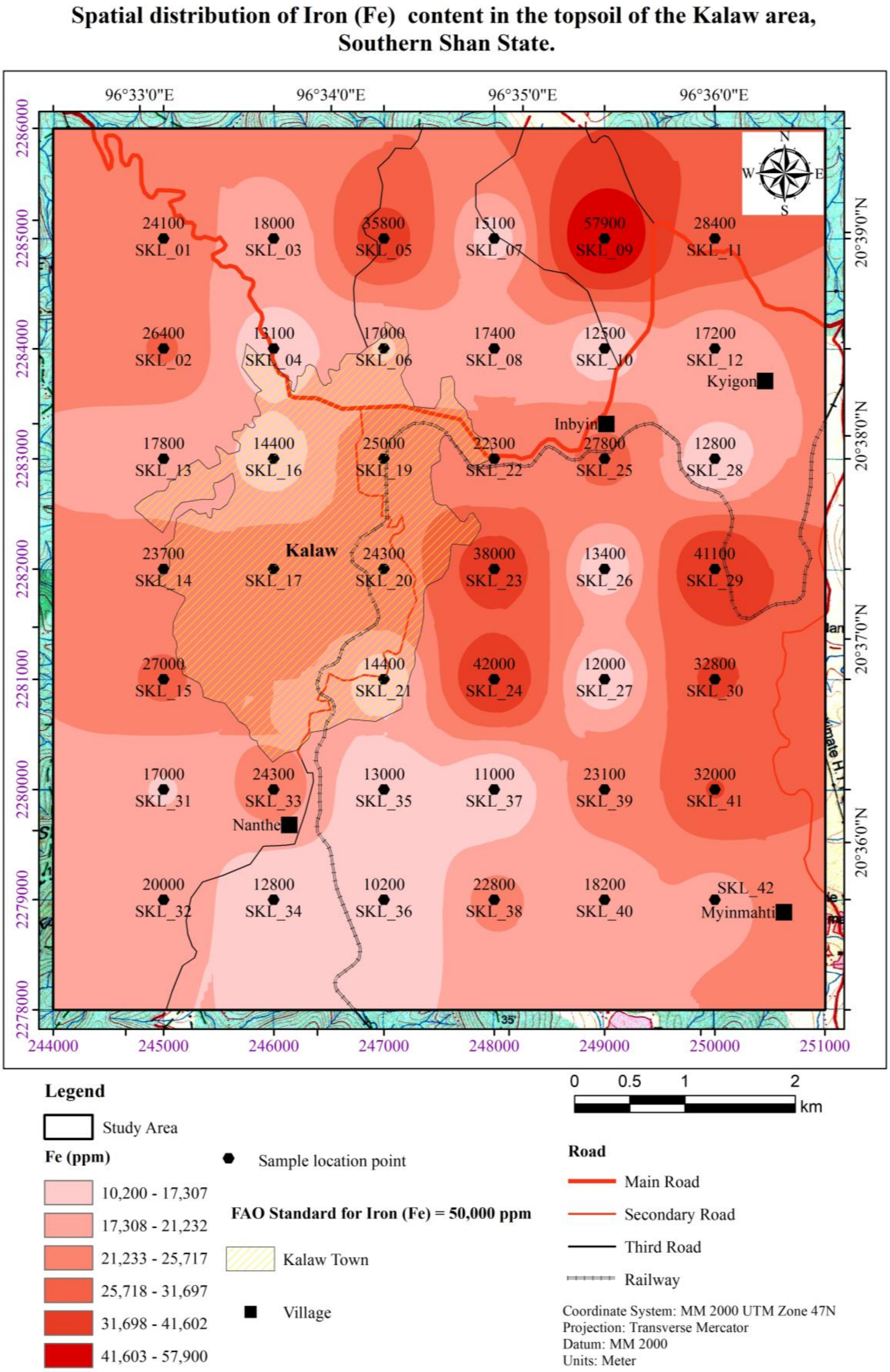

Figure 14. Spatial distribution of Iron (Fe) content in the topsoil of the Kalaw area,

Southern Shan State.

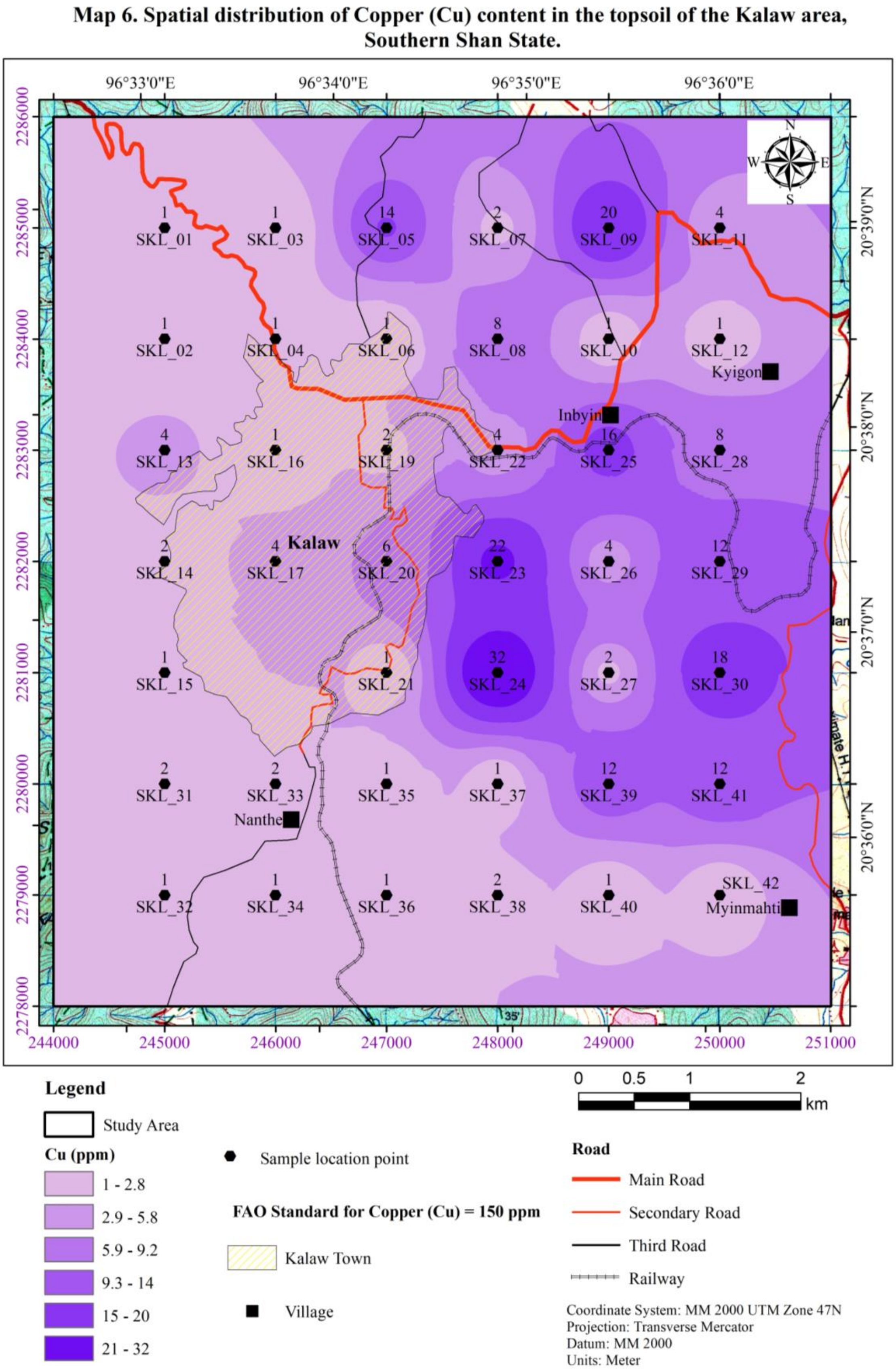

Figure 15. Spatial distribution of Copper (Cu) content in the topsoil of the Kalaw area, Southern Shan State.

5. Conclusion

According to the assay results of topsoil samples from Kalaw town, the levels of Zinc (Zn) and Copper (Cu) are low. However, although Lead (Pb) and Chromium (Cr) levels at the seasonal crop cultivation site (SKL_03) and the site near the dump site (SKL_30) lie below the FAO's standard limit, they are observed to be slightly elevated compared to other locations. Similarly, Nickel (Ni) levels at the Avocado farm site (SKL_05) are below the FAO's standard limit but are also found to be slightly higher when compared to other sites. In areas where reddish-brown Terra Rossa soil is found, the concentration of iron (Fe) is slightly elevated. This is not primarily due to anthropogenic factors, but rather because Terra Rossa soil is inherently rich in iron (Valter Boero et al., 2024). The enriched levels of Manganese (Mn) are not related to human activities but are the result of the primary geochemical composition of shale and dolostone rock layers, manganese accumulation during sedimentation/diagenesis, and the residual accumulation of insoluble manganese phases during subsequent weathering processes. Shale is formed from the sedimentation of clay muds in ancient seabeds. During this sedimentary process, manganese present in the seawater reacts with the clay sediments and tends to accumulate as manganese carbonate minerals (e.g., rhodochrosite) (Igor et al, 2008). When dolostone layers are subjected to weathering, the carbonate minerals they contain dissolve, leaving behind insoluble manganese compounds which accumulate. Consequently, soils forming on dolostone tend to become manganese-rich soils (Manganiferous Soils). For instance, in the Piedmont region of North America and in South Africa, the weathering of dolomite rock layers has resulted in the formation of black soils containing up to 8-14% manganese (Adams, R. K et al., 2023). Although the accumulation of heavy metals in the soils of Kalaw town has not yet reached a level that poses a threat to the ecosystem and human health, it is necessary to systematically control the discharge of waste from industrial activities and the excessive use of chemical fertilizers and pesticides in agricultural practices. This study will contribute to the comprehensive monitoring and assessment of soil pollution status in Kalaw town, the identification of pollution sources, and the future environmental protection and management efforts.

6. Acknowledgement

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