Nutrient Interception by a Riparian Forest Buffer Strip from Adjacent Orchard near Reservoir: Two Case Studies in Taiwan

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Summary

Two case studies, including Techi reservoir located at Taichung county, central Taiwan, and Feitsui reservoir located at Taipei county, northern Taiwan, were selected to study the effect of nutrient interception by a riparian forest buffer strip receiving the adjacent orchard region by applying the high and low quantity of chemical fertilizers, respectively. The widths of riparian forest buffer strip are at least 50 meters in these two case study sites. The composition, spatial variability and seasonal changes of cations and anions in soil solution collecting from orchard, interface and riparian buffer zones were analyzed to control the water quality in two water reservoirs. The results indicated that the soil nutrients in the orchard near Techi reservoir, especially for the ions of phosphate, K, Ca, Mg, and ammonium-N, can be significantly intercepted by a forest buffer strip within 30 meters. Owing to no any application of chemical fertilizers in the orchard near Feitsui reservoir since 1987, the nutrient concentration of different ions in soil solution is very low. This low concentration of ions in soil solution released from orchard region near Feitsui reservoir can be intercepted in the interface area between the orchard region and forest buffer strip. The results also indicate that the width of riparian buffer strip needs at least 10 meters to intercept the soluble nutrients under this very low input of chemical fertilizers. We make sure that enough width, at least 30 meters of riparian buffer strips for these two case studies, can be regarded as a nutrient sink to intercept the soil nutrients soluble from orchard region and keep good water quality in the reservoirs.

Key Words: Riparian forest buffer strip, buffer width, eutrophication, soil solution, water quality, interception, nutrient sink.

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1. Introduction

The forest has a function of conserving the source of water, reducing the soil erosion, reducing the earth's surface runoff and blocking the nutrients to move. The riparian forest buffer strip of the forestry deals in and collects in the water area is very important for keeping of river quality. Hewlett (1985) pointed out that applying a large amount fertilizer above and below of the forest buffer strip, if there is forest buffer strip, then the concentration of nutrients of the groundwater does not have obvious change, but under having forest buffer strip, the concentration of nutrients in the groundwater will rise by a wide margin, and will influence the quality of the stream. It also indicated that forest buffer strip take the importance to safely guard the quality of water source in the forest.

The riparian buffer strip means that it is the transition ecosystem area between ecosystem of land and water ecosystem, this area is often the important nutrient source of a water ecosystem. Therefore, riparian buffer strip is the important factor considered to maintain the productivity of river basin. The riparian buffer strip means there is circumference of a river or reservoir which has a width of the plants of forest, bush or grasses, etc. It has certain interception or filters the function of the nutrients flowed from both sides of river, and it does not cause the eutrophication for reservoir or rivers.

A lot of research papers have pointed out that the riparian buffer strip can buffer the nutrients depend on the difference of the pollutant by buffering width, there must be 10 to 60 meters at least, it can play its function and can protect the water quality of the river or reservoir (Ding and Chen, 1981, 1984; Hsieh and Chen, 1989; Chen *et al*., 1989; Lowrance, 1992; Jordan, 1994; Hsieh *et al*., 1994; Chen and Liu, 1994, 1995; Chen, 1995). In addition, Iowa State University Agroforestry Research Team (IStART) (1994) also indicated that the more plant varieties planting at the both sides of river, for instance trees, short bush and grass as the riparian buffer strip, the more promotion the water quality after the four years buffer function.

Lowrance (1992) indicated that the function of denitrification will be very fast if the groundwater table of the riparian forest soil is within 60 centimeters from surface soil. Therefore, it can remove a large number of nitrate nitrogen from the groundwater in the forest. Jordan et al. (1993) also indicated that riparian forest buffer strip can significantly intercept the nitrogen flow from the corn field which located at both sides of corn field, in term of nitrate nitrogen, organic carbon and soluble organic nitrogen. The strong reduction condition with high electric potential (Eh) (>500 mv) can increase the denitrification function. In addition, Arthur and Fahey (1992 and 1993)

also indicated that seasonal changes of groundwater do not significantly influence the soil chemical properties. Ambus and Lowrance (1991) proposed that denitrification function is to change the nitrate nitrogen of soil solution to produce different influences because of different situations located at the different areas.

Lowrance *et al*. (1984a) and Pinkowski *et al*. (1985) indicated that riparian forest buffer strip can regard as nutrient sink and can reduce the nitrate nitrogen, total nitrogen, calcium, and magnesium which flowed from the area of agricultural cultivation of both sides of river. In addition, research also indicated that the net retention percentage to nutrients of forest buffer strip are N 68 %, Ca 39 %, P 32 %, Mg 23 %, Cl 7 % and K 6 %, respectively (Lowrance *et al*., 1984a, 1984b; Chichester, 1976; Kilmeret *et al*., 1974).

Hsia *et al*. (1994) indicated that there are no obvious differences of phosphorus and potassium concentrations of the soil solution in the artificial forest zone of *cryptomeria* between applying fertilizer and without applying fertilizer. The ammonium nitrogen in the soil solution of bush forest zone is all very low, the nitrate nitrogen concentrations is relative high in the surface water only, the other nutrients are all not different compared to those of applying fertilizer. In addition, this study also indicated that the buffer function of the nutrient in the soil of the riparian zone, are dependent on the soil factor, land use, growth condition of cover plant, and the ability of absorbing nutrient of plant roots. In addition, many researches also indicated that the riparian forest zone can absorb the majority of nitrogen and phosphorus flowed from the farmland, orchard or tea garden, and it can intercept about 70-90 % of total nitrogen and nitrate-N in the width of 20 meters of riparian zone (Lowrance *et al*., 1984c; Peterjohn and Correll, 1984; Jacobs and Gilliam, 1985; Haycock and Pinay, 1993).

King *et al*. (1984) indicated that the heavy rain can produce the soil suspension particle flowed into the stream after the riparian forest was clear cut. All the nutrients concentrations are higher than those of regulation of nutrient ions in the river, including magnesium, potassium, nitrate-N and sulfuric acid. It is obvious that we can make a good soil and water conservation practice to protect the water quality in the natural forest ecosystem. Romkens *et al*. (1973, 1974) also indicated that using a large amount of fertilizer and applying the urine of livestock for increasing the highest crop productivity will promote a large amount of phosphorus concentration flowing into the river system through surface runoff. Therefore, it will accelerate the eutrophication of rivers, creeks and water reservoir. Taiwan Province Government (1981) proposed a technical method to set up the riparian buffer strip in the both sides of reservoir which the width of riparian buffer zones should be at least

15 to 30 meters in the horizontal distance.

Lowrance *et al*. (1988) have studied and pointed out, in the good area of planting and growing, Cs-137 brings in the forest highest from bounded content in place of 30 meters, later reduced sharply. Copper *et al*. (1983) and Copper and Gillian (1987) showed that the riparian forest strip can deposit Cs-137 and enough width of riparian forest buffer strip can block the movements of the nutrients effectively. In addition, Jordan *et al*. (1993) also use bromine ion as the trail of pharmaceutical, and then concluded that 30 meter of forests buffer width can intercept the soil nutrients. Lin (1988) indicated that, at least 10 meters of buffer width, can effectively reduce the concentrations of phosphoric acid and total phosphorus in the soil solution. Chen (1995), Chen and Liu (1994, 1995) and Chen *et al*. (1996) found that salt content of various nutrition in the soil solution is quite low in trial zone of about 10 meters between orchard and forest Feitsui reservoir.

The objective of this article is to review the function of riparian buffer strips, also known as riparian forest zone, on intercepting the excess nutrients discharged from the upper part of the fertilizers or pesticides application area in two case studies in Taiwan (Ding and Chen, 1981, 1984; King *et al*., 1984; Lin, 1988; Chen, 1989, 1995; Chen and Liu, 1994, 1996; Hsia *et al*., 1994; Hsieh *et al*., 1989, 1995).

2. Materials and Methods

2.1 Techi reservoir near Taichung city, Central Taiwan

The first study site was located at Techi reservoir in central Taiwan near Taichung, which the elevation is about 1400 meter (Fig. 1). The soil sampling regions are shown in the left side. The orchard regions are region A to region I. The interface regions are region X, Y and Z. The riparian forest buffer zones are region J, K, L, M, N, P and Q region. The control regions are S and T. The soil solution sampling regions are shown in the ride side. The orchard regions are region A and B. The interface regions are region C and D. The riparian forest buffer zones are region E, F, G, H, I, J, K and L regions. The control regions are Y and Z. The study project was conducted from 1988 to 1989.

The precipitation of the site is 2600 mm/yr and mean annual air temperature is 17 ℃. The site of study soil is classified as Dystrochrepts, an Inceptisols with ochric epipedon in the upper 20 cm and low base saturation less than 70 %. 50 tons/ha of organic fertilizer and mixed chemical fertilizer including 100 kg ammonium sulfate/ha and 200 kg/ha of calcium perphosphate, and 100 kg/ha of potassium chloride were applied into the study site from March to April every year. Mixed chemical

fertilizer including 200 kg potassium chloride/ha and 200 kg/ha of calcium perphosphate is also applied into the site on August every year.

2.2 Feitsui reservoir near Taipei city, Northern Taiwan

The second case study site was located at Feitsui reservoir in northern Taiwan near Taipei, which the elevation is about 300 meter (Fig. 2). The rain water sampling regions are shown with number from 1 to 5. The orchard regions are region 1 and 2. The interface regions are region 3. The riparian forest buffer zones are region 4 and 5. The control regions are region 6. The soil solution sampling regions are shown with English letter from A to J. The orchard regions are region A to region F. The interface region is region G only. The riparian forest buffer zones are region H and I regions. The control regions are J. The study project was conducted from 1993 to 1995.

The precipitation of the site is 3400 mm/yr and the mean annual air temperature is 27 ℃. The site of study soil is classified as Dystrochrepts, Inceptisols with ochric epipedon and low base saturation less than 70 %. No any chemical fertilizers were supplies since 1987.

2.3 Design of sampling of soil solution in experimental sites

One orchard size of 30 m x 50 m and one riparian forest buffer strip of 60 m x 50 m were selected as experimental plot in each site. Two separate forest areas of 20 m x 20 m were also selected as the forest control site.

Four and 8 collection apparatus of soil solution were set up in the orchard area and forest buffer strip of Techi site, respectively, sampling at the site after every storm from January, 1988 to December, 1989.

Six and 3 collection apparatus of soil solution were set up in the orchard and forest buffer strip of Feitsui site, respectively, sampling at the site after every storm from July, 1993 to June, 1995.

2.4 Chemical analysis of soil and soil solutions

The items of soil physical and chemical properties of two sites were determined including soil pH, organic carbon content, cation exchange capacity (CEC), exchangeable bases including Ca, Mg, K, and Na, extractable ammonium-N and nitrate-N, and Bray's No. 1 extractable P.

The items of cations and anions of soil solutions were determined including pH, electric conductivity, K, Na, Ca, Mg, ammonium-N, nitrate-N, phosphate-P, F, Cl, Br, and Sulfate ions.

3. Results and Discussion

3.1 Variation of soil nutrients in Techi site

The distribution of different soil characteristics and all kinds of nutrition in the different

regions collected from different sampling time during the period from 1987 to 1989 (Fig. 3). The soil pH ranged from 3.8 to 4.9, which increased with increasing soil depth. The results also indicated that nutrients, such as phosphorus, potassium, calcium and magnesium sampled from riparian forest strip are higher than those of orchard region. Nitrate-N and sodium have significantly differences between orchard and riparian forest strip region. The potassium, sodium and magnesium concentration at orchard, riparian forest strip intersection and forest buffer strip all have similar monitoring concentration. In surface soil samples, ammonium-N concentration in riparian forest strip is significantly higher than that of orchard region, it is result in the high soil organic matter content in the riparian forest strip. The various nutrients of the subsurface soil samples in different research districts also have the same trend.

The data analysis and spatial variation of surface soil (0-20 cm depth) and subsurface soils (20-40 cm depth) in 1988 showed that pH value has the trend of decrease, but pH has no significant differences between orchard area to riparian forest buffer strip. Ammonium-N, nitrate-N, extractable phosphorus, potassium, magnesium, organic matter, total nitrogen amount and organic nitrogen content, in riparian forest buffer strip of 1st district that have the tendency to significantly increase, then significantly decrease in the 2nd district and the 3rd district of riparian forest buffer strip.

This result also revealed that if we can do good soil and water conservation practices and there is enough width of reservoir forest regions, then the nutrients in soil of orchard district can only be moved to the 1st district of forest buffer strip, about 10 meters from the orchard district, and the concentration of different nutrient ions have already obviously reduced in the collected soil solution.

3.2 Variation of soil solution nutrients in Techi site

The mean concentration of various ions and variations in different soil solution samples of the research area are shown in Fig. 4. Because the farmers used the chemical fertilizer all the year in the study site before the experiment, potassium, calcium, magnesium, available phosphorus and total phosphorus content in soil solution are all have significantly higher concentration in the orchard district. But, the available phosphorus and total phosphorus content drop rapidly in the intersection region between orchard district and forest buffer strip, and keep a low level content in the forest buffer strip. It revealed that the phosphorus in the soil of this research district can pollute the water quality of groundwater or reservoir. Because ions are moved differently between potassium, sodium, calcium, and magnesium ions, therefore, there are different distribution situations shown in the soil

solution. Chlorine ion and ammonium nitrogen had higher amounts in the upper zone of riparian forest buffer strip, which has significantly differences compared to those of other nutrients. It means that the concentration of Na, Ca, Mg, phosphate and total phosphorus are significantly decreased in the riparian forest strip. The proposed width of riparian forest buffer strip is at least 30meters in Techi site.

3.3 Principal component analysis (PCA) in Techi site

1. The Principal component analysis of soil nutrients

Selecting surface soil samples (0-20 cm) sampling on February 9, 1988, as an example, after analyzing of various nutrients by principal component analysis (Fig. 5). The result of this PCA analysis indicated that the variation of first two principal components can account for 85.6 % of total variance in Techi site. Among them, the first principal component accounts for 62.5 %, and the second principal component accounts for 23.1 %. The first principal component can distinguished obviously soil sample of orchard district and forest buffer strip, and the bounded area between orchard district and forest buffer strip can also defined. Because of applying chemical fertilizers and changes of topography, it makes the relatively great variability of various nutrient contents in the surface soil samples of orchard district. This can also be shown by the analysis result of the first axis of PCA. In addition, potassium, sodium, calcium, magnesium and extractable phosphorus content can reach positive correlation more than 0.86. The subsurface soil samples also have the same trend as surface soil samples by principal component. It revealed that potassium, sodium, calcium, magnesium and extractable phosphorus contents in the soils which have the high to low concentration gradient change from orchard district to forest buffer strip.

2. The Principal component analysis of soil solution nutrients

The principal component analysis of average nutrient contents in soil solution of the Techi site are shown in Fig. 6. It clearly reveal that the samples of the lower forest zone (regions of F, G, H, I, K, L), higher forest zone (regions of C, D, E, J) and forest control area (region Y & Z) were regarded as the same groups and they were distinctly different from the orchard samples (regions A and B). The result of this study also revealed that the variation of the first principal component accounts for 51.5 % of total variation, and the principal component with calcium, magnesium, extractable phosphorus and total phosphorus content have apparent positive correlation. The variation of second principal account for 23.9 % of total variation, and the principal component with ammonium-N and chloride contents has apparent positive correlation. It is noteworthy that the nutrient content of lake water sample was closer similar to that of the samples collected from the

interface regions between orchard area and forest zones (Fig. 6). We also found that the contents of sodium, calcium and magnesium of lake water are relatively higher than those of riparian forest buffer strip.

3.4 Variation of soil nutrients in Feitsui site

This surface soil and subsurface soil samples near ten soil solution sites were analyzed for soil pH value and various nutrients. The pH value ranged from 4.1 to 4.6 except forest soil in check area, which is slightly high. The soil organic carbon content of surface soil and subsurface soil samples are relatively high, ranged from 20 to 35g/kg.

Because this research area has not applied the chemical fertilizer since 1987, therefore, the concentrations of different cations and anions in soil or soil solution are very low. For the nutrients, there is no variation tendency on the space in surface soil (0-20 cm) and subsurface soils (20-40 cm). The result also indicated that the organic nitrogen content account for more than 93 % of the total soil nitrogen content in all samples, except few samples. There is a tendency of decreasing from orchard area to forest buffer zones for available phosphorus content, reducing from 160 mg/kg to 11 mg/kg. The organic phosphorus content in study site has 80-90 % of the total phosphorus content in most surface soils and subsurface soils in the study.

3.5 Variation of soil solution, rainwater and reservoir lake water nutrients in Feitsui site

The pH, EC value and the concentrations of potassium, sodium, calcium and magnesium in soil solution, rainwater and reservoir lake water are shown in Figs. 7, 8, and 9. The pH value does not have obvious change in soil solution from Fig. 7, ranged from 4.9 to 5.1. In forest check area, the pH value is 5.8. The pH value of rainwater is about 5.6. The pH value of reservoir lake water is about 6.7, based on the standard values in reservoir water quality ranged from 6.5 to 8.5. The EC value of soil solution and rainwater is quite stable ranged from 0.04 to 0.07 dS/m, except very few samples. This may have something to do with the plant decomposing or enrich effect. The EC value of reservoir lake water is quite stable, which revealed that the changes with time is difficult at the present stage in water quality of Feitsui site.

In general, the concentrations of different cations and anions in soil solution are very low (Fig. 8 & 9). The ions of K, Na, Ca and Mg in soil solution are always found in slightly higher concentration in interface region between orchard area and forest buffer strip, and these results also indicated that this interface area can be regarded as a nutrient sink shown as Fig. 8 and Fig. 9. The average concentration of sodium ion in reservoir lake water is higher than those of soil solution. In Fig. 9, we also found that the concentration of calcium, magnesium are less than 1.0 and 0.2 mg/L

in the soil solution, and there is no any effect on the water quality of Feitsui reservoir.

The concentrations of ammonium-N, nitrate-N, fluorine ion, chlorine ion, phosphate ion and sulfate ion in soil solution, rainwater and reservoir lake water (Fig. 10 to 12). From Fig. 10, there is no any ammonium-N and phosphate ions can be detected in the soil solution even in the orchard area. Only one can be found in the rainwater sample is its highest concentration in 1.4 mg/L, but the average concentration is under 0.1 mg/L. The concentration of nitrate-N is almost less than 1.0 mg/L, even more in orchard area near detection limit. The concentration of fluorine ion is also quite low, only forest buffer strip and reservoir lake water is slightly high, about 0.3 mg/L, and the others sample in the area was under 0.2 mg/L. There is no significant variation in the study area for these ions. The average concentration of chlorine ion studied in the site is about 5 mg/L and the reservoir lake water is slightly high, about 7 mg/L (Fig. 11).

In addition, the concentration of phosphate ion near zero in different water samples, which revealed that there is no any eutrophication phenomena in the Feitsui reservoir. About sulfate ion, it is the lowest in the rainwater, about 2.5 mg/L. It is slightly higher from orchard area to forest buffer area, about 4 mg/L. There is the highest concentration of sulfate ion in the reservoir lake water, about 8 mg/L, perhaps, which was produced by the soil solution flowing into the reservoir directly or by rainfall. Therefore, the proposed width of riparian forest buffer strip in Feitsui site should be at least 20 meters.

3.6 Spatial and seasonal variation of ions in soil solution of Feitsui site

Because of concentration of various nutrients in soil solution is not high, so that the spatial variations of water quality in different sampling times are also acceptable in the study area. But it still has higher value in the orchard area. In addition, the pH value and the concentration of K and Na ions in the soil solution have a relatively higher spatial variation. The seasonal variations have significantly differences depend on the kind of ions and quantity of precipitation for Ca, Mg, Nitrate-N and phosphate ions in the site. It is very important that the practices of soil and water conservation in hillside need more notice to prevent the eutrophication phenomena was occurred.

4. Conclusion

Nutrients in the soil solutions of orchard near Techi reservoir located in central Taiwan, especially for the ions of phosphate, K, Ca, Mg, and ammonium-N can be significantly intercepted by a forest buffer strip within about 30 meters based on the case studies during 1988 to 1989.

Low concentration of soil solution in the orchard near Feitsui reservoir also can be intercepted

in the interface area between the orchard and forest buffer strip, which also indicated that the width of riparian buffer strip needs at least 10 meters to intercept the soluble nutrients under no any application of chemical fertilizers in the experimental sites during 1993 to 1995.

We can make sure that enough width, at least 30 meters, of riparian buffer strips for these two case studies can be regarded as a nutrient sink to intercept the excess soil nutrients soluble from orchard region and to keep the good water quality in the reservoirs based on these two case studies in Taiwan.

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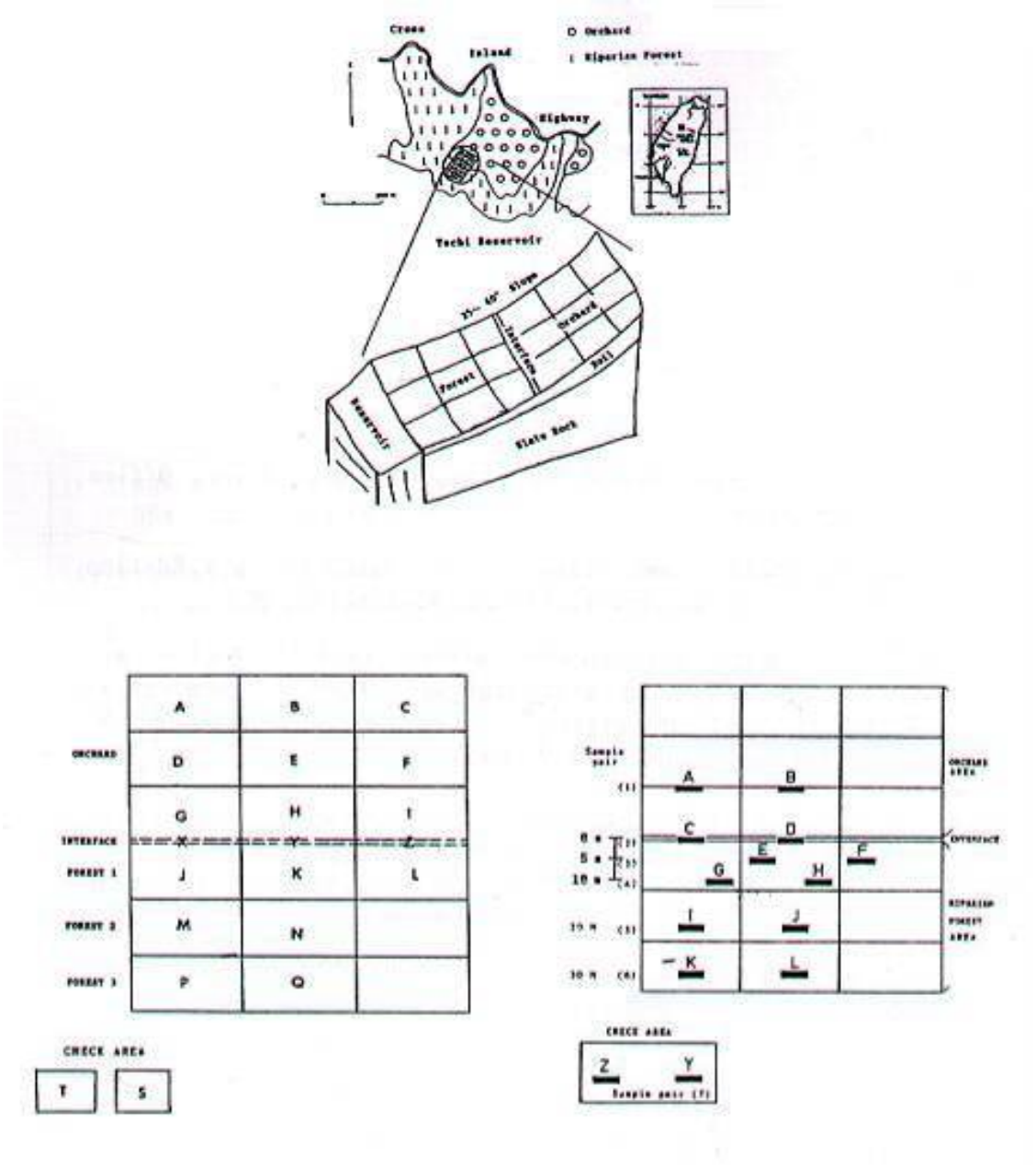


Fig. 1. The geomorphology and sampling sites of Techi reservoir study area in 1988 and 1989.

Notes: The soil sampling regions are shown in the left side. The orchard regions are region A to region I. The interface regions are region X, Y and Z. The riparian forest buffer zones are region J, K, L, M, N, P and Q region. The control regions are S and T.

The soil solution sampling regions are shown in the ride side. The orchard regions are region A and B. The interface regions are region C and D. The riparian forest buffer zones are region E, F, G, H, I, J, K and L regions. The control regions are Y and Z.

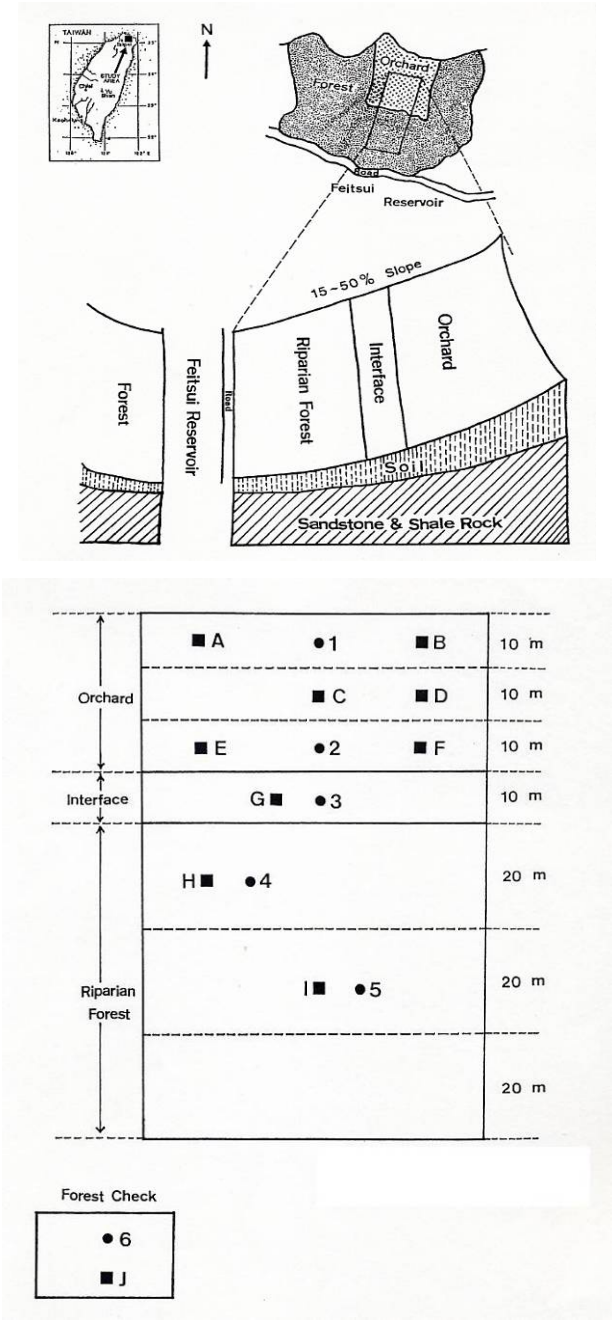


Fig. 2. The geomorphology and sampling sites of Feitsui water reservoir study area in 1993 and 1994.

Notes: The rain water sampling regions are shown with number from region 1 to 5. The orchard regions are region 1 and 2. The interface region is region 3. The riparian forest buffer zones are region 4 and 5. The control region is region 6.

The soil solution sampling regions are shown with English letter from A to J. The orchard regions are region A to region F. The interface region is region G only. The riparian forest buffer zones are region H and I. The control region is J.

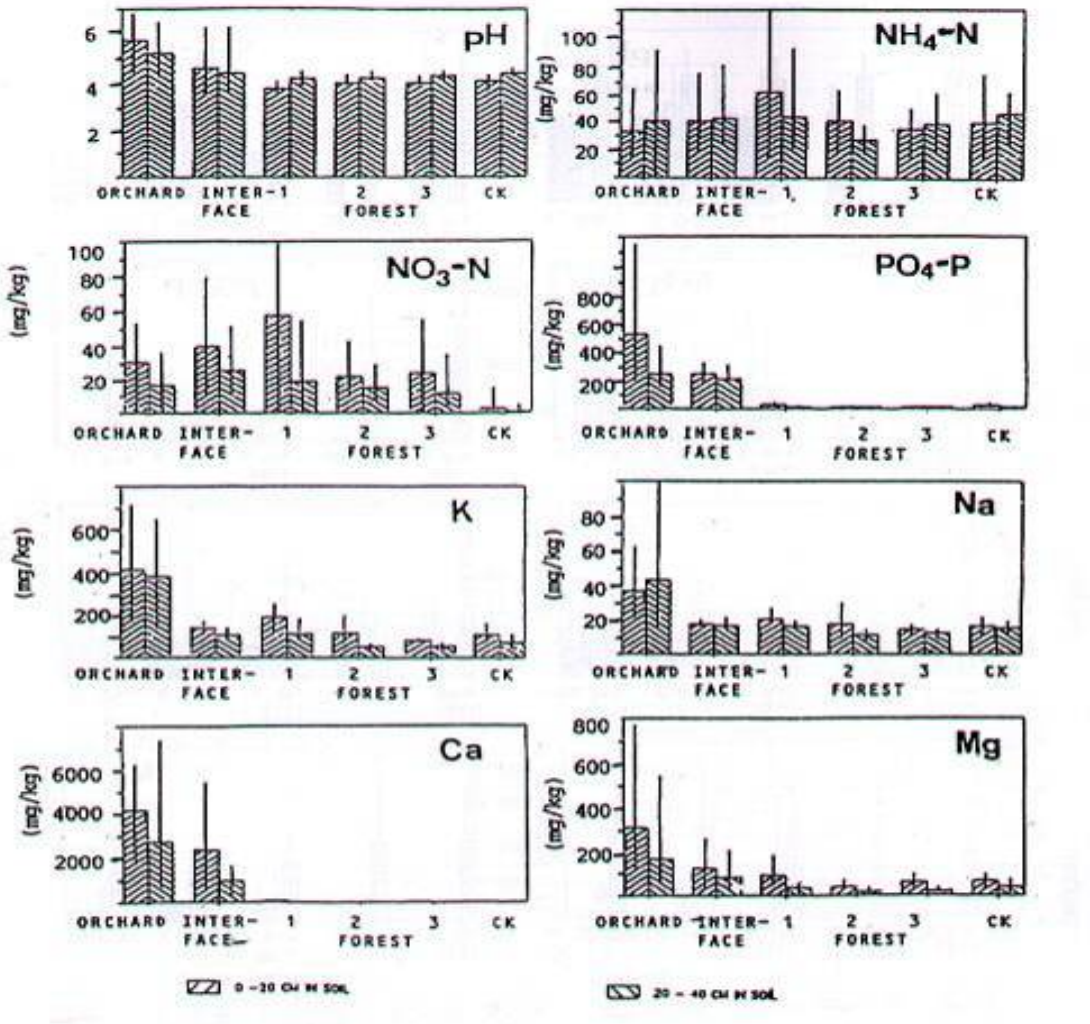
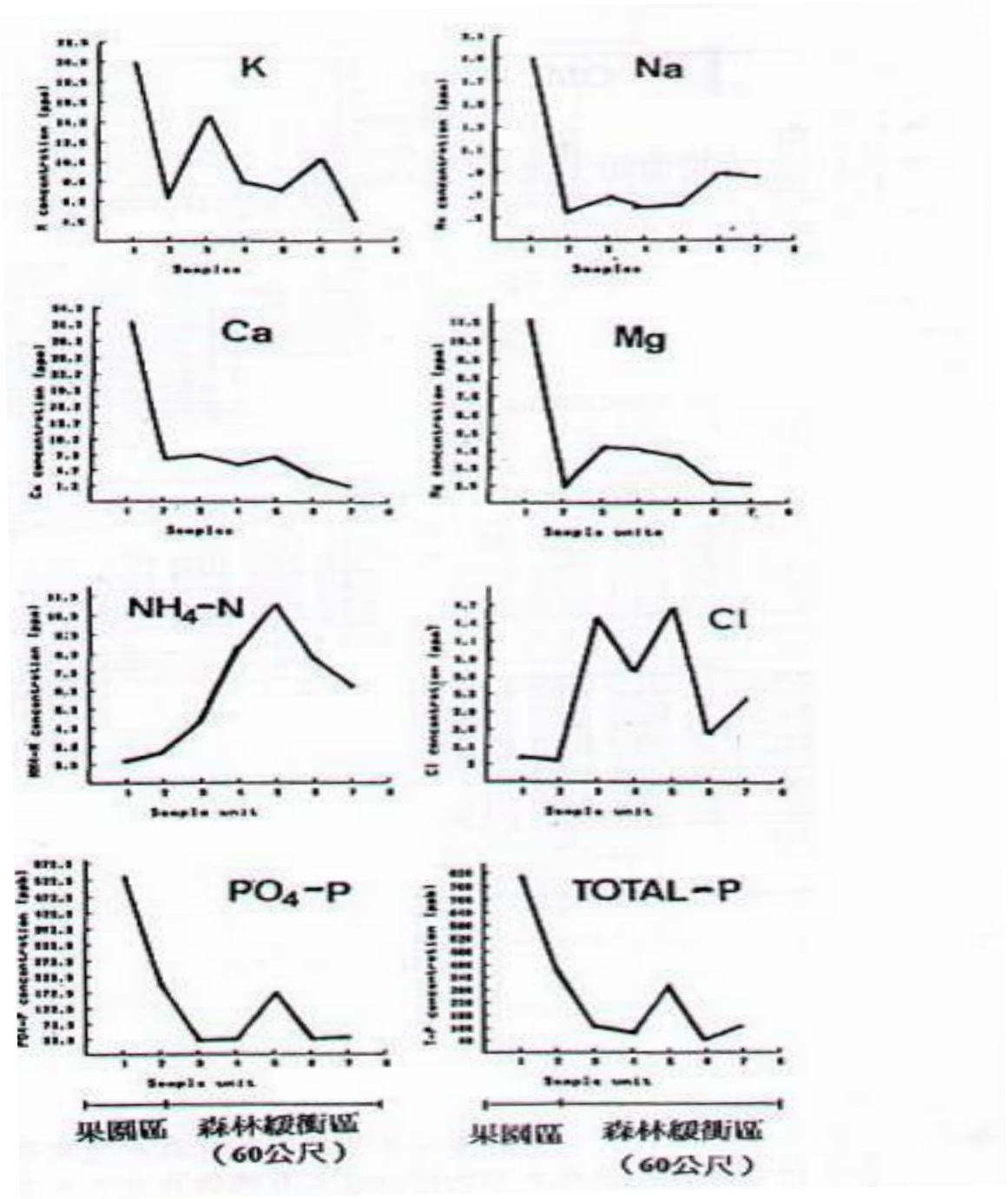


Fig. 3. The distribution of different cations and anion ions in the different soil depths (0-20 cm in the left side and 20-40 cm in the right side for each ions) collected from different sampling area of Techi reservoir.

Notes: Number 1, 2, and 3 are riparian forest zones.



Orchard region | Riparian forest region (60 meters width) | Orchard region | Riparian forest region (60 meters width)

Fig. 4. The distribution of different cations and anion ions in the soil solution collected from different sampling area of Techi reservoir.

Notes: Number 1 is orchard region, #2 is interface region, and from # 3 to #8 are riparian forest zones and the width of this buffer zones is 60 meters.

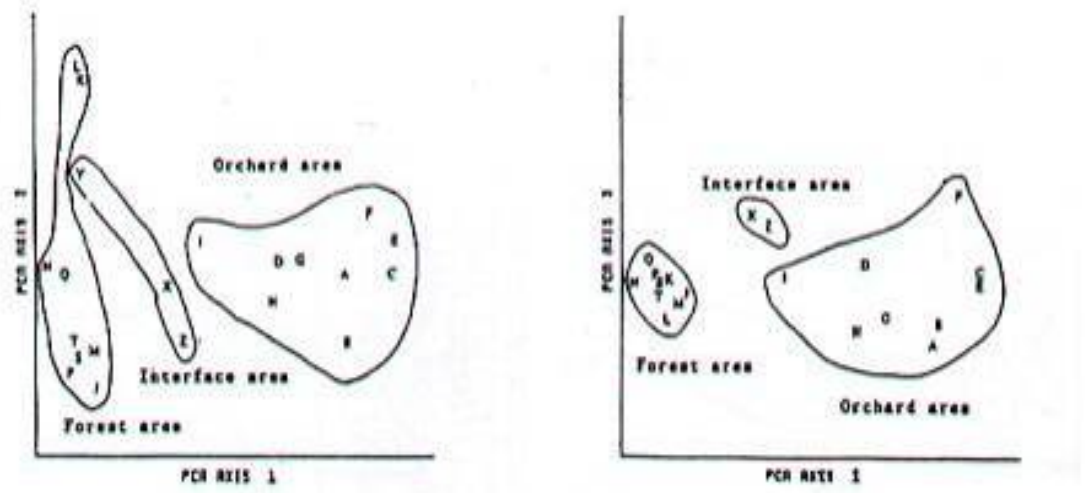


Fig 5. The distribution of the soil samples (0-20 cm depth) collected in 1988, relative to the first three principal component axes of the Techi reservoir.

Notes: The soil sampling regions are shown in the left side of fig. 1. The orchard regions are region A to region I. The interface regions are region X, Y and Z. The riparian forest buffer zones are region J, K, L, M, N, P and Q. The control regions are S and T.

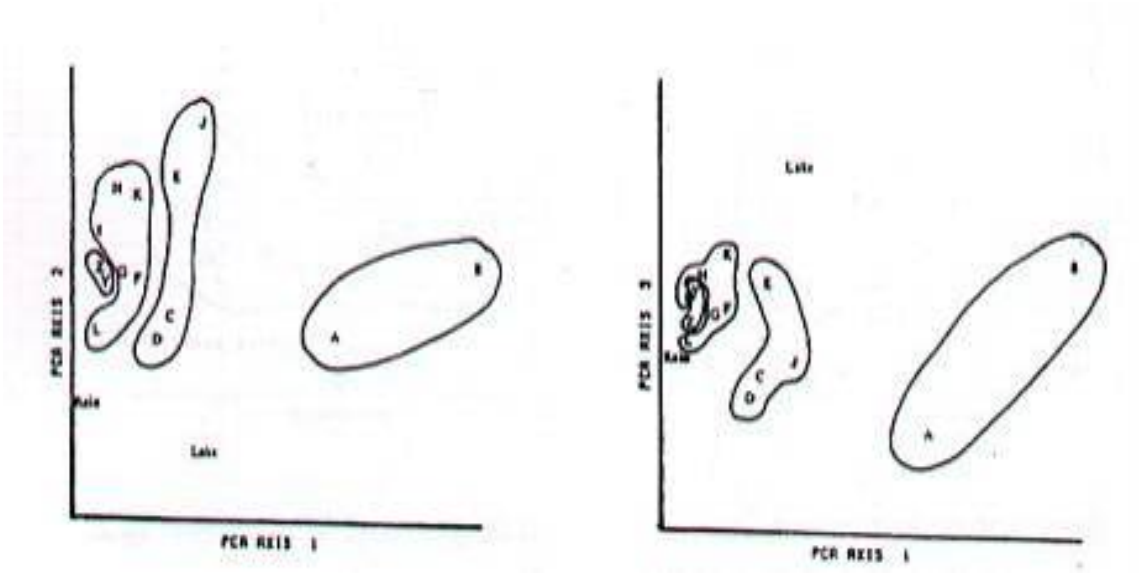


Fig. 6. The distribution of cations and anions of the soil solutions collected in 1988 relative to the first three principal component axes of the Techi reservoir

Notes: The soil solution sampling regions are shown in the ride side of Fig. 1. The orchard regions are region A and B. The interface regions are region C and D. The riparian forest buffer zones are region E, F, G, H, I, J, K and L regions. The control regions are Y and Z.

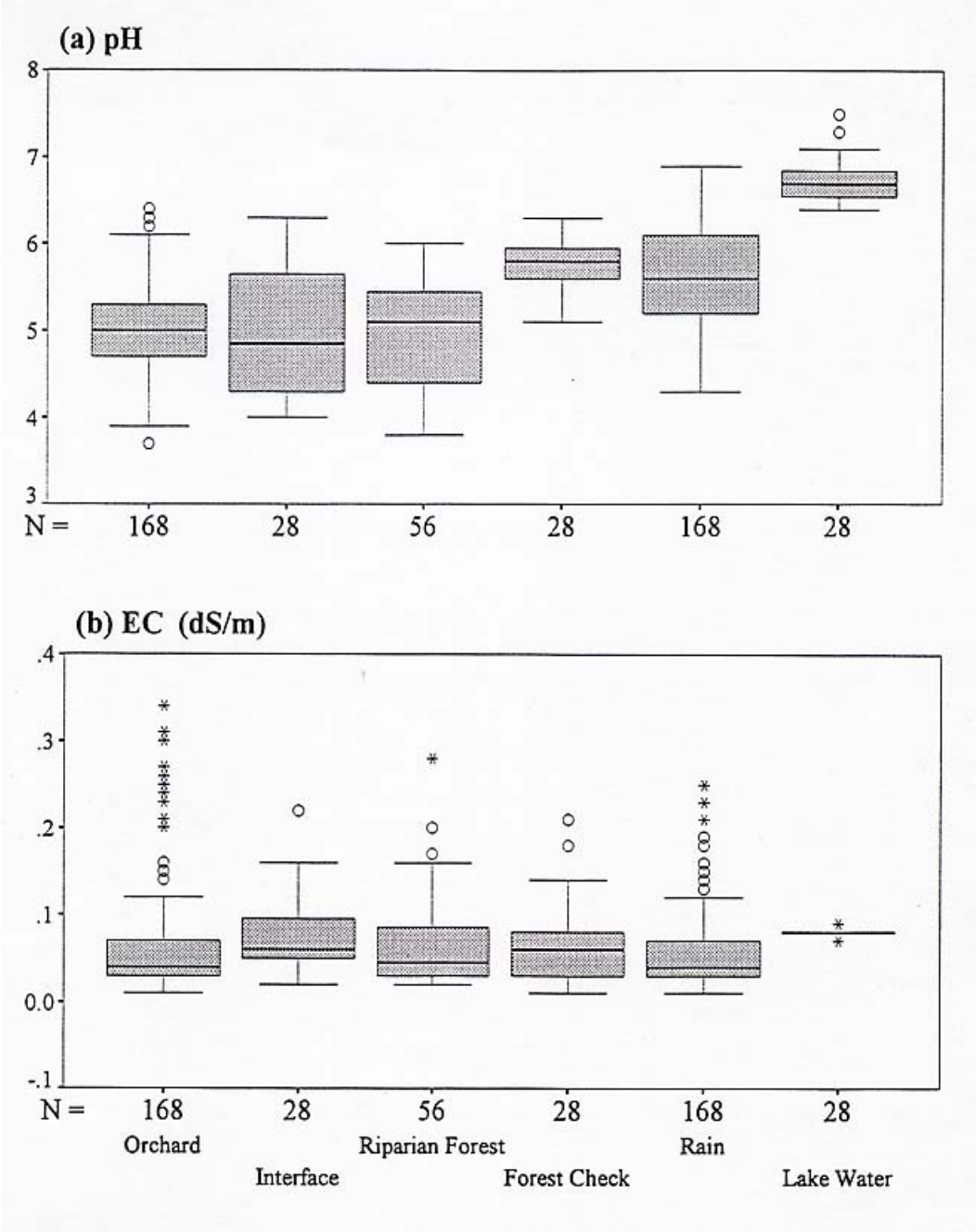


Fig. 7. The distribution of pH values and EC values in the soil solution collected from different sampling area of Feitsui reservoir near Taipei city.

Notes: The values in the black boxes ranged from 25th % to 75th % of total range. The black bar is medium value (50 % of total range). The values of the bars ranged from minimum value to maximum value. The circle value (O) is the 1.5 times of observation values of black boxes far from the 75th % of the total range values. The star value (*) is the 3 times of observation values of black boxes far from the 75th % of the total range values. N is total sampling number.

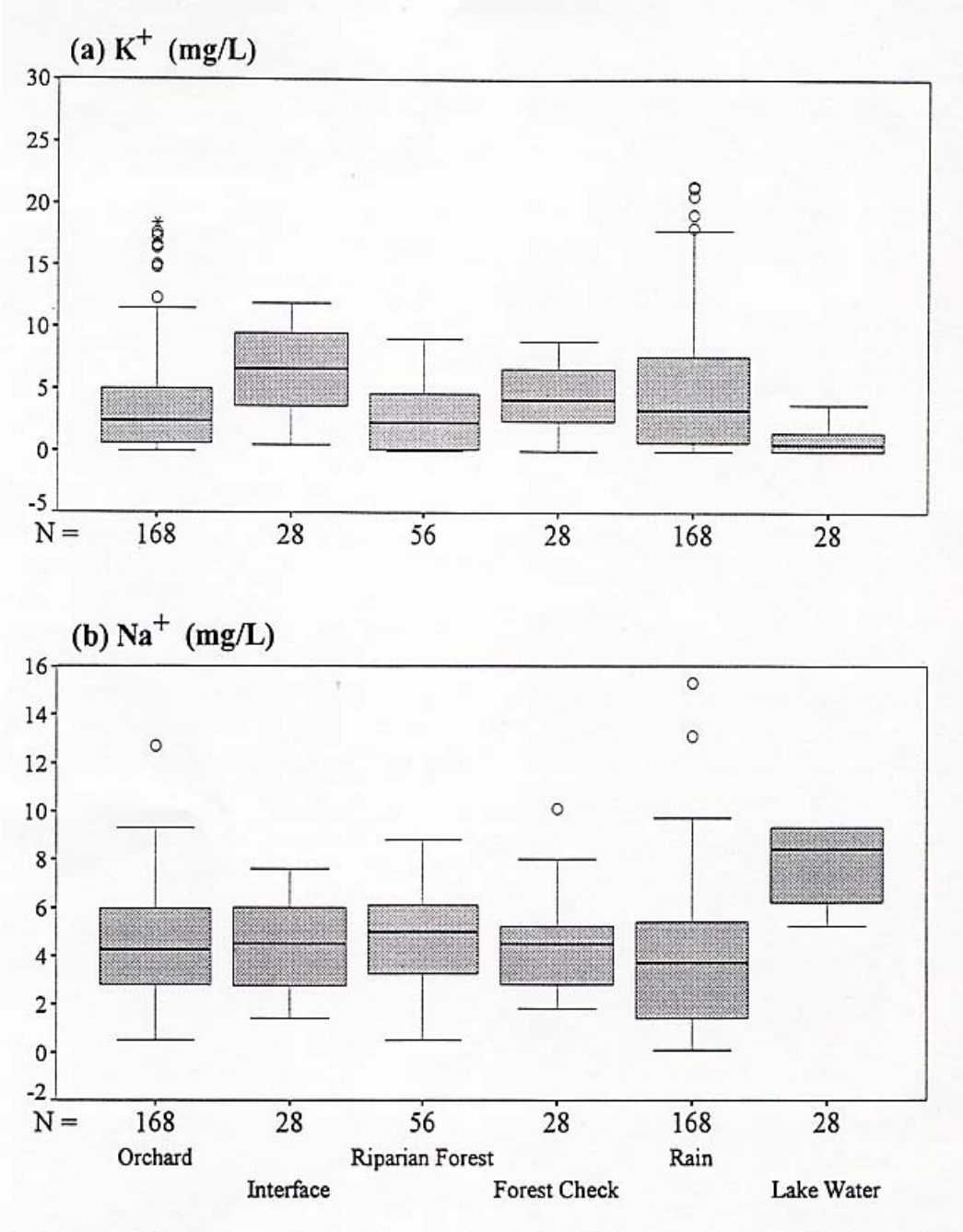


Fig. 8. The distribution of potassium and sodium ions in the soil solution collected from different sampling area of Feitsui reservoir near Taipei city.

Notes: The values in the black boxes ranged from 25th % to 75th % of total range. The black bar is medium value (50 % of total range). The values of the bars ranged from minimum value to maximum value. The circle value (O) is the 1.5 times of observation values of black boxes far from the 75th % of the total range values. The star value (*) is the 3 times of observation values of black boxes far from the 75th % of the total range values. N is total sampling number.

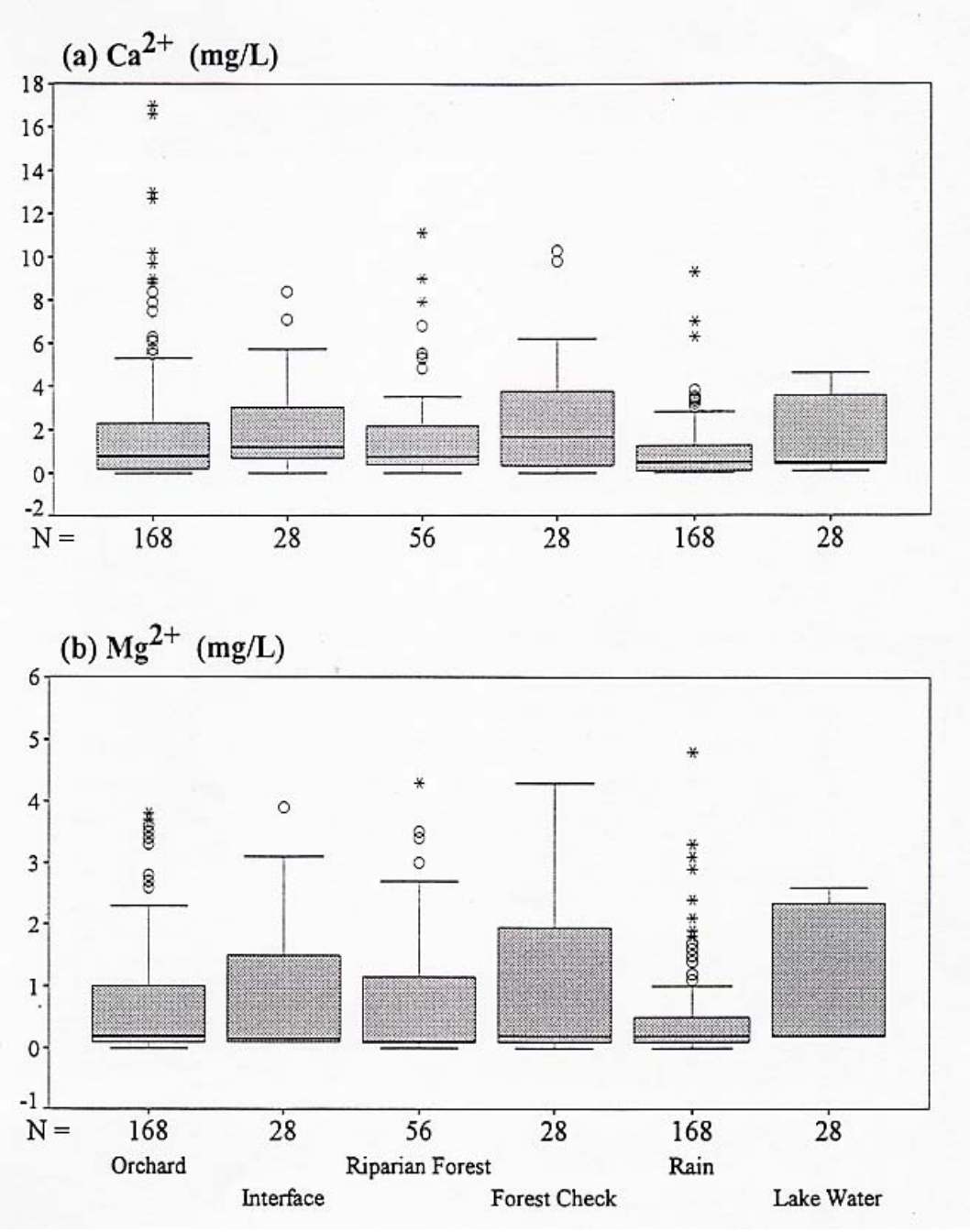


Fig. 9. The distribution of calcium and magnesium ions in the soil solution collected from different sampling area of Feitsui reservoir near Taipei city.

Notes: The values in the black boxes ranged from 25th % to 75th % of total range. The black bar is medium value (50 % of total range). The values of the bars ranged from minimum value to maximum value. The circle value (O) is the 1.5 times of observation values of black boxes far from the 75th % of the total range values. The star value (*) is the 3 times of observation values of black boxes far from the 75th % of the total range values. N is total sampling number.

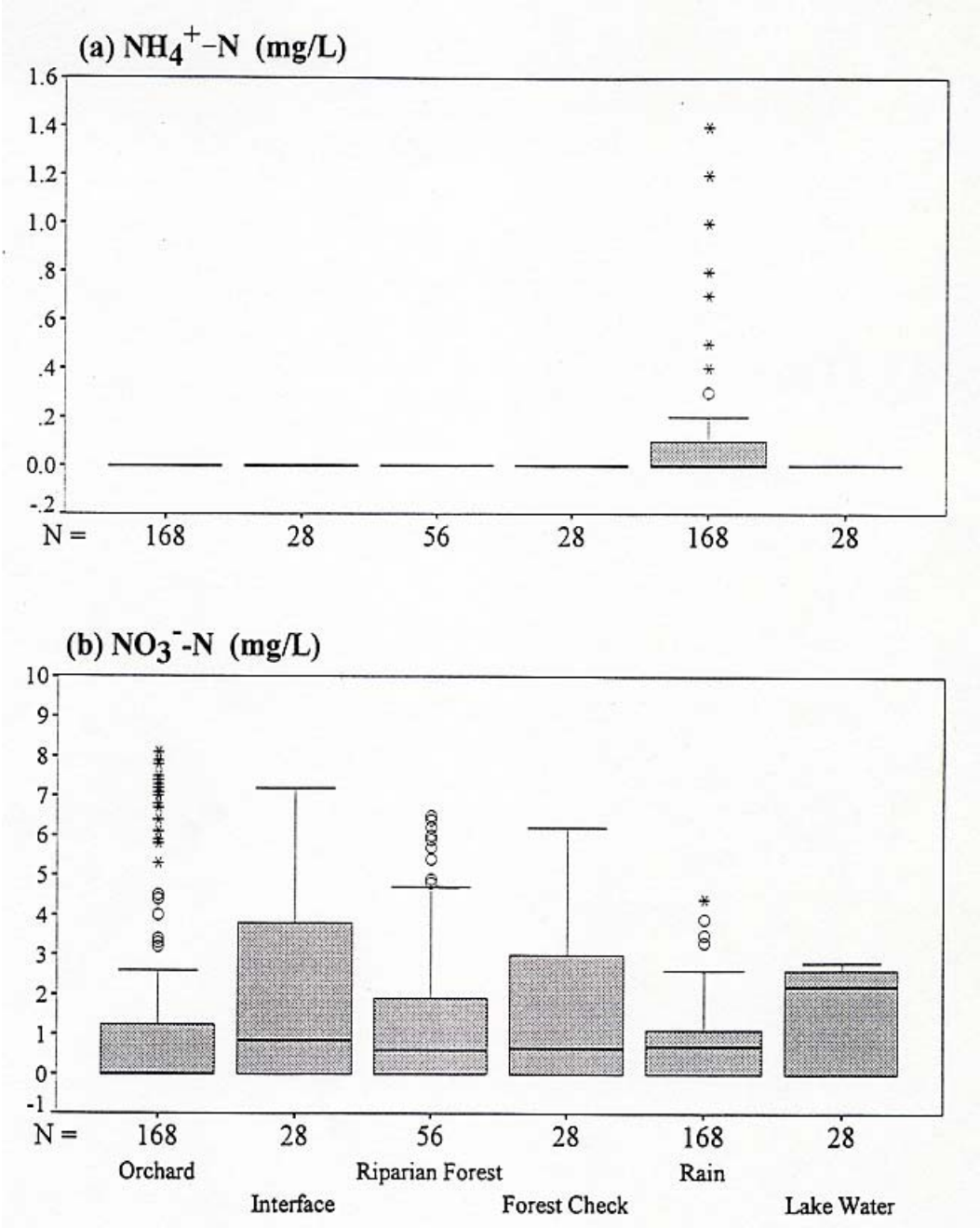


Fig.10. The distribution of ammonium nitrogen and nitrate nitrogen ions in the soil solution collected from different sampling area of Feitsui reservoir near Taipei city.

Notes: The values in the black boxes ranged from 25th % to 75th % of total range. The black bar is medium value (50 % of total range). The values of the bars ranged from minimum value to maximum value. The circle value (O) is the 1.5 times of observation values of black boxes far from the 75th % of the total range values. The star value (*) is the 3 times of observation values of black boxes far from the 75th % of the total range values. N is total sampling number.

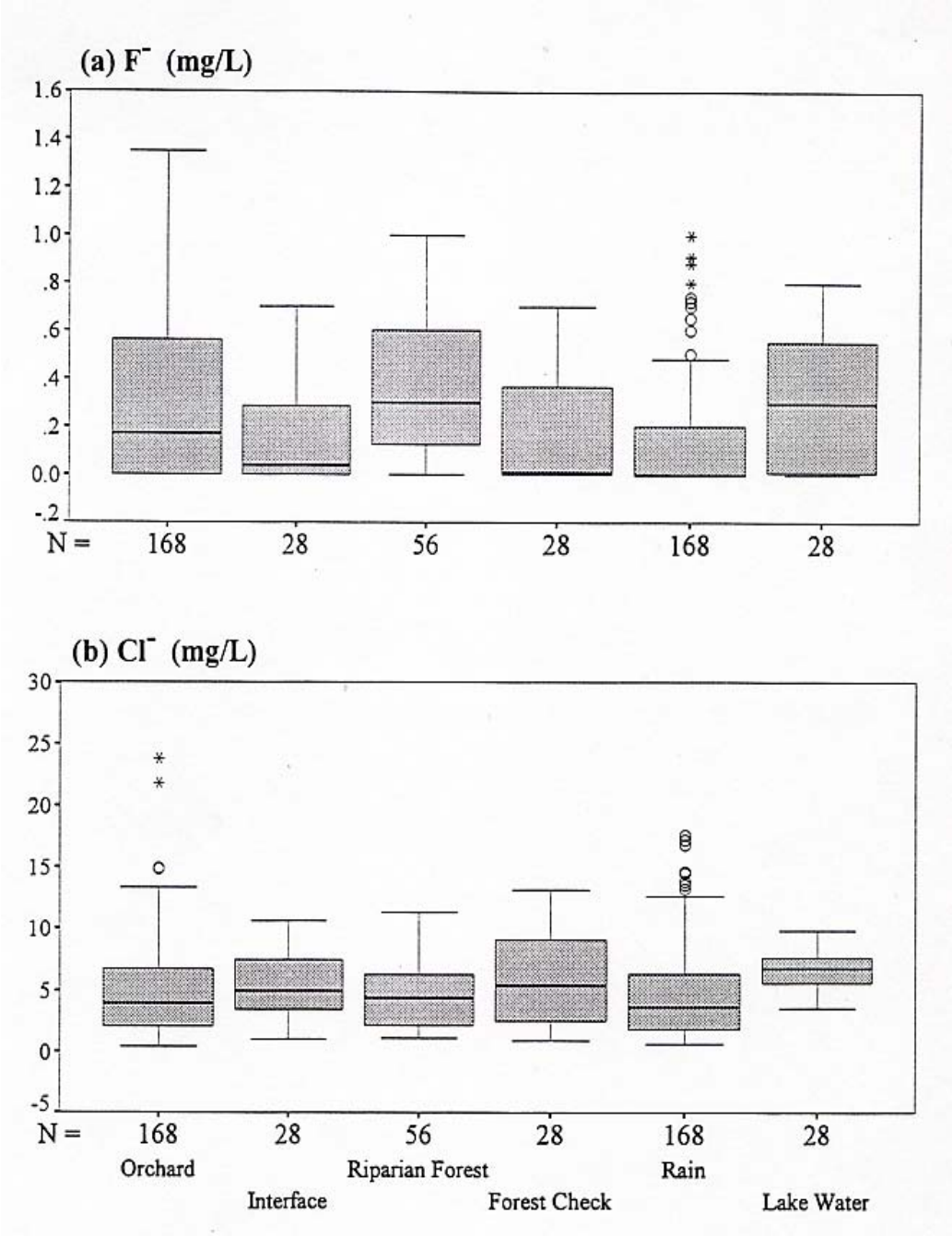


Fig.11. The distribution of fluoride and chloride ions in the soil solution collected from different sampling area of Feitsui reservoir near Taipei city.

Notes: The values in the black boxes ranged from 25th % to 75th % of total range. The black bar is medium value (50 % of total range). The values of the bars ranged from minimum value to maximum value. The circle value (O) is the 1.5 times of observation values of black boxes far from the 75th % of the total range values. The star value (*) is the 3 times of observation values of black boxes far from the 75th % of the total range values. N is total sampling number.

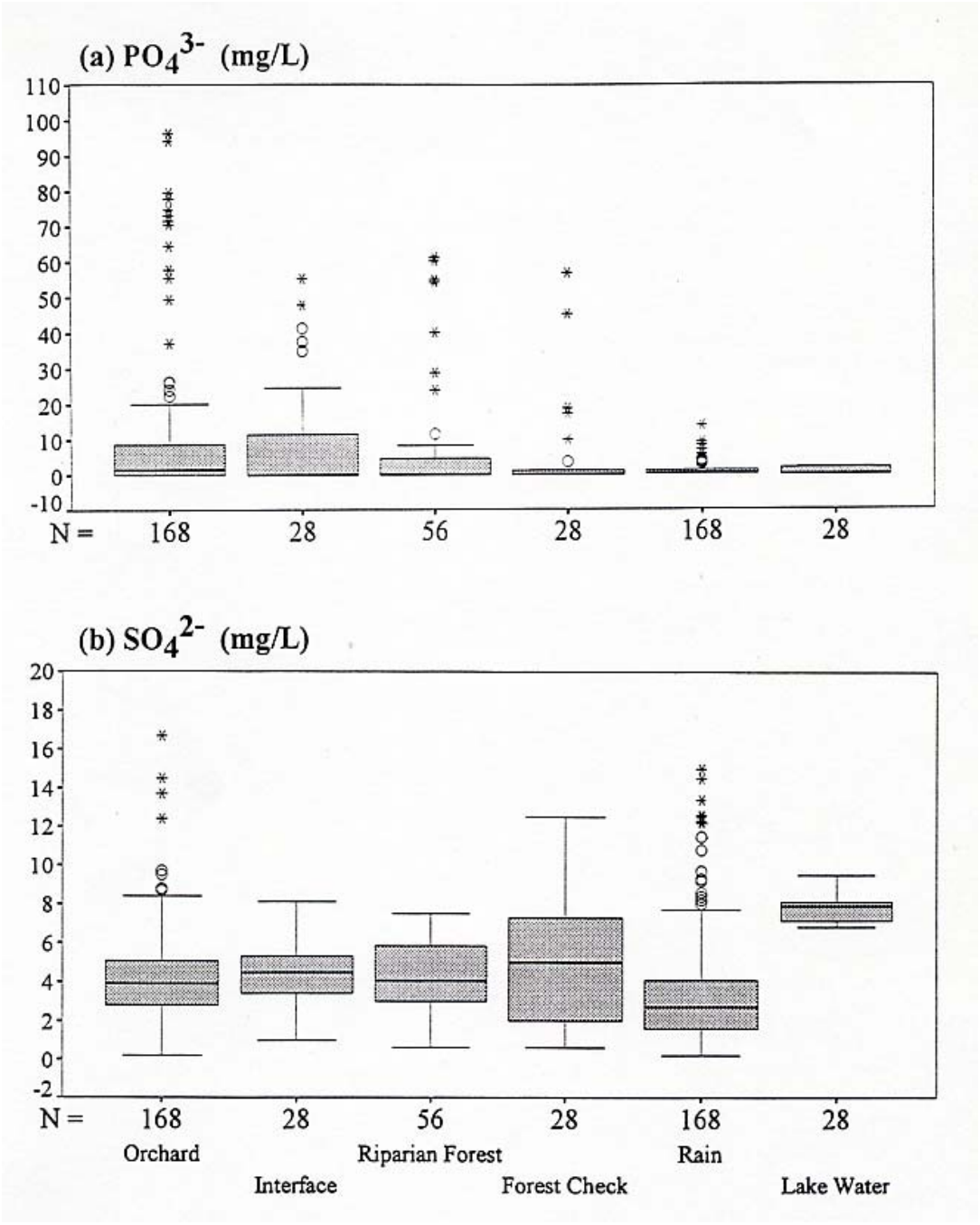


Fig.12. The distribution of phosphate and sulfate ions in the soil solution collected from different sampling area of Feitsui reservoir near Taipei city.

Notes: The values in the black boxes ranged from 25th % to 75th % of total range. The black bar is medium value (50 % of total range). The values of the bars ranged from minimum value to maximum value. The circle value (O) is the 1.5 times of observation values of black boxes far from the 75th % of the total range values. The star value (*) is the 3 times of observation values of black boxes far from the 75th % of the total range values. N is total sampling number.