Chapter 3

NUTRIENT EXPORT COEFFICIENTS

3.1 Introduction

In Chapter 1, a distinction was made between descriptive and predictive use of the modeling methodology. Planning for proper lake quality management necessitates the prediction of the impact of projected land use on lake water quality. Measurement of a yet-to-be realized impact is clearly impossible. Instead, the planner must extrapolate impact assessments from other, similar watersheds, possibly in the form of annual export coefficients. Thus nutrient loading estimates associated with watershed land uses are necessary for lake trophic quality management planning.

In this chapter, annual nutrient export coefficients, identified in the comprehensive literature survey by Beaulac (1980), are presented in tabular and graphical form. The criteria employed in the identification of these "approved" export coefficients are described. To a great extent, these criteria reflect the importance of good experimental design in the collection of nutrient flux data for the determination of export coefficients. Also discussed in some detail are recommended criteria to be considered by users of this methodology in the selection of export coefficients. To facilitate this selection process, the tabulated nutrient export coefficients are presented along with data on related characteristics. These include watershed location, precipitation, soil type, and other site-specific features that might affect nutrient runoff. The user may then match these qualities with the characteristics of the application lake watershed so that reliable export coefficients are chosen.

3.2 Criteria Employed in the Selection of Export Coefficients for this Manual

In screening nutrient export coefficients reported in the literature, Beaulac (1980) established certain acceptance criteria. To a considerable degree, these criteria are reflective of good experimental design employed in watershed studies. So that the analyst may understand the approximate reliability that can be attached to the tabulated export coefficients (presented below and in the Appendix), important screening criteria are discussed. For elaboration of this topic, see the Appendix.

1. Accuracy In statistical terms, accuracy exists when the expected value for an estimator lies close to the true value. Inaccuracy in a study frequently results from faulty experimental design. Therefore, to evaluate accuracy, one must have a good conceptual knowledge of the characteristic of concern. This includes an understanding of causal relationships as well as temporal and spatial variability if relevant. For nutrient export coefficients, accuracy is likely if the researcher a) employed design controls for extraneous variables not of immediate interest, b) incorporated into the analysis all causal factors not removed from influence, and c) used good statistical sampling design (see the Appendix). As an example, if the researcher is interested in agricultural row crop runoff, he/she must either exclude all other runoff sources from the test watershed, or include consideration of the additional sources when analyzing the results. If it is known that row crop runoff is quite dependent upon major storms and that particulate material is important, then the design must reflect these factors.

2. Precision Like accuracy, precision is a statistical term. An estimate is precise if it is estimated with low error. Good sampling design (see the Appendix) is a necessary but not sufficient condition for precision. Precision is also affected by the number of samples taken and the amount of useful information acquired per sample. Therefore, in screening literature export coefficients, Beaulac (1980) looked for accurate experimental designs including frequent sampling (particularly if the observations are dependent).
3. Representativeness For the nutrient export coefficients to contribute to reliable lake trophic management planning, the analyst must carefully match the characteristics of candidate export coefficient watersheds with the application lake watershed (see section 3.3). This requires comprehensive information on the export coefficient watersheds. Therefore, Beaulac (1980) looked for information on characteristics such as geographic location, precipitation, watershed size, soil type, fertilizer application (when appropriate) and other important land use features. This is vital to the watershed matching process which dictates export coefficient choice.
4. Temporal Extent of Sampling Nutrient budgets and input-output lake models are generally based on yearly increments so that the meterologically-induced annual variations in nutrient export and lake quality are effectively removed from analysis. Since weather and climate have a similar effect on export coefficients, only yearly values were accepted by Beaulac. The alternative, extending values

reported for fractions of a year, must be rejected because of methodological problems.

5. <u>Nutrient Flux Estimation</u> There is no "best" method for combining concentration and flow data to estimate mass flux. However, the short discussion in the Appendix on sampling design and flux estimation describes preferred techniques. Only export coefficients estimated under documented methods deemed relatively unbiased are reported herein.
6. <u>Concentration and Flow Data</u> Since flow is the prime determinant of nutrient mass flux, as a rule only those export coefficients estimated with continuous flow data are reported. Most lake models and nutrient loading criteria are based on total nutrient concentrations. Therefore, preferred studies were those that reported total nutrient concentrations. Beyond that, since bioavailability (see the Appendix) is an issue receiving increasing attention, fractional forms of the nutrients are provided herein when reported in the original study.

3.3 Export Coefficient Selection Criteria for the Modeler

Probably the most important task that the analyst performs in applying the methodology in Chapter 2 is selecting the phosphorus export coefficients. Most of the other steps are quite explicit in the description of the task to be conducted and in the associated uncertainty (if any). Export coefficient choice, on the other hand, benefits from the experience of the analyst in the general topic of land use-nutrient flux relationships. The problem associated with faulty export coefficient selection is one of supplemental, or hidden, uncertainty. This refers to prediction uncertainty that is unknown to the analyst and thus is not part of the uncertainty accounting process. Hidden uncertainty results from inexperience; the analyst believes that a choice of high and low export coefficients covers the true phosphorus loading when in fact it does not. This leads to bias in the prediction and additional risk in planning. Knowledge of the causal factors behind nutrient flux from land use activities and thoughtfulness in matching the application watershed with candidate export coefficient watersheds can significantly reduce supplemental uncertainty.

There are two important issues to consider when selecting export coefficients. First, one must try to match the application lake watershed and candidate export coefficient watersheds as closely as possible on the basis of causal determinants of phosphorus loading. Second, the range of export coefficients selected (i.e., the high and low values) should reflect the total uncertainty for that characteristic. Factors important in watershed matching are outlined in detail after a short discussion of phosphorus loading uncertainty.

Uncertainty in phosphorus export may arise from 1) natural variability, 2) error and bias associated with the measurement and estimation of the export coefficient, 3) error and bias associated with the representation of phosphorus export in the application watershed by an export coefficient estimated at another point in space and/or time, and 4) uncertainty in land use, population, etc., projections. It was noted in Chapter 2 that the phosphorus model standard error contains some phosphorus loading estimation error associated with the model development data set. As a result, the description of export coefficient selection--for the purpose of loading error estimation--is quite specific. Thus not all uncertainty components identified above are necessarily included in each set-of-three (high, most likely, and low) export coefficients choice.

One point should be made concerning the first item listed above: natural variability. The nutrient export coefficient tables exhibit natural variability (in addition to measurement and estimation error) among the export coefficients presented. This is cross-sectional variability which in part represent various, and different, conditions in the nutrient export coefficient watersheds. This must be distinguished from natural longitudinal variability, which reflects variability in export from a single watershed over time (see section 3.4 for histograms exhibiting cross-sectional and longitudinal variability). It is likely that longitudinal variability is smaller in magnitude than cross-sectional variability, since the causative factors for longitudinal variability are relatively homogeneous (in comparison to the causative factors for cross-sectional export coefficient variability). Since export coefficients are chosen for single watersheds (over time), it is longitudinal export variability that is important (in addition to extrapolation error and bias). Unfortunately, there is little multi-year data on nutrient export in single watersheds, so when needed, the estimation of longitudinal nutrient export variability is necessarily subjective.

The second issue mentioned above for consideration in selecting export coefficients is the process of matching the application lake watershed and candidate export coefficient watersheds according to causal determinants of nutrient export. To facilitate this matching process, an outline is presented below listing important causative nutrient export factors according to land use activity.

1. Forest Land Use

   The range of phosphorus export coefficients is very narrow (.019 - .830 kg/ha/yr), and it is difficult to specify any one factor as the determinant of loading in a particular watershed. Much of the variation among coefficients is probably within the range of experimental or sampling error.

a. Species Type

  i. Pine-coniferous softwoods have demonstrated higher rainfall interception capacity and evapotranspiration rates than have hardwoods. A number of investigators report that annual streamflow was reduced about 20% below that expected for the hardwood cover, 15 years after experimental watersheds in the Southern Appalachians had been converted from a mature deciduous hardwood cover to white pine (Swank and Douglass, 1977, 1974; Swank et al., 1972; Swank and Miner, 1968). Therefore higher nutrient loads could develop from tributaries draining hardwoods than from tributaries draining softwoods.

  ii. Some hardwoods such as alder (Alnus sp.) are nitrogen fixers. Brown et al. (1973) reported both higher nitrate concentrations and higher nitrogen loads from alder watersheds than from those streams that drained primarily douglas fir and western hemlock (for streams in western Oregon).

b. Soil Type, Bedrock, and Parent Material

Dillon and Kirchner (1975) observed that forested watersheds with sandy soils overlying granitic igneous formation had one-half the phosphorus output than did forested watersheds with loam soils overlying sedimentary formations. Loam soils are higher in nutrients and more erodable than sands and gravels; sedimentary formations have higher leachability and erodability. Therefore soils and substrate types such as these (loams and sedimentary formations) may cause shifts toward the higher end of the phosphorus export range.

c. Vegetation Age

Maturity is a function of species type (among other characteristics). This factor is important only in very young, newly vegetated forests. In this sense, "young" refers to trees of less than five years of age. Woodlots of this age do not have a canopy developed enough to reduce rainfall impact energy. Therefore soil in young forests are more disrupted than soils in mature forests (see Disturbed Watershed, below). The result is higher runoff and greater sediment phosphorus flux from young forests.

d. Climate

This appears to be the major determinant of export of phosphorus from forests. Areas of the country that exhibit warm climates with high rainfall (such as the pacific northwest and southeastern piedmont regions) are associated with high productivity, high runoff, and high phosphorus export.

e. Disturbed Watersheds

i. Deforestation/timber harvest

Watersheds with ongoing timber harvest tend to have higher nutrient export than do undisturbed systems. This is because deforestation: 1) blocks the nutrient uptake pathway; 2) raises forest floor temperature; 3) increases the frequency of drying and wetting (weathering); 4) increases microbial activity; and 5) increases the nutrient pool by contribution of dead organic material (slash). Therefore, nutrient output is increased. (The amount of increase depends on the extent of the watershed under cultivation.)

ii. Forest fire

Nutrient export due to fires can increase over the normal range of export for undisturbed forests, but this will depend upon the severity of the burn (% watershed burned) and the type of fire (crown vs. brush (understory) fire) (Wells, 1971; Pritchett, 1979).

iii. Fertilization

Nutrient export will increase only if fertilizers are applied directly on the stream. This practice is currently not very common nationwide. Increases in nutrient export will last only for a short time period (one or two runoff periods), and will depend on the extent of areal coverage of the fertilizer and fertilizer type (nitrogen or phosphorus). (Moore, 1970, 1975; Fredriksen et al, 1975; Stay et al., 1978).

2. <u>Agricultural Land Use: Crops</u>

a. Soils

Because soils are exposed for long time periods (late fall, winter, early spring), they will influence the magnitude of the phosphorus load released from the watershed.

i. Sandy/gravel soils 1) do not erode easily, 2) have a low cation content, and 3) cause a general downward flow of water to the groundwater (high infiltration capacity). Thus phosphorus export via runoff is low.

ii. Clay soils (clay loams, silt loams etc.) have a 1) high cation content (high phosphorus adsorption capacity), 2) high erodability, and 3) low infiltration capacity. Therefore phosphorus export via runoff is high.

iii. Organic soils have 1) limited phosphorus retention capacity, 2) low infiltration capacity, and 3) high nutrient content. As this soil is used for cultivation, it decomposes rapidly. Therefore phosphorus export via runoff is high.

b. Fertilizer Type and Amount

i. The type of fertilizer is not as significant as the time of application. Partially because of this, manure-type fertilizers are thought to often cause high phosphorus export because manure is frequently applied on frozen soils in winter or early spring. When combined with snowmelt and high rainfall/runoff periods, the result is very often high export of phosphorus and nitrogen. If application is followed with soil incorporation, phosphorus and nitrogen export is substantially reduced (Minshall et al., 1970; Klausner et al., 1976; Converse et al., 1976; Hensler et al., 1970).

ii. Heavy amounts of fertilizer (either manure or commercial grade) applied above the recommended rate will cause increases in nutrient export. The recommended rate is dependent upon the amount and availability of nutrients in the soil (to growing crops).

c. Tillage Practices

i. Conventional tillage methods, in which the ground is left fallow during non-growing periods and crop residues are removed at harvest, are a prime cause of high amounts of nutrient export (lead to high erosion of soils, etc.).

ii. Conservation tillage methods ideally have conservation of soil, water and energy as the primary objective. These methods will reduce the export of nutrients. Among the conservation tillage methods are 1) nonmoldboard tillage, such as chisel plowing, that does not use a moldboard plow and involves fewer tillage operations than conventional moldboard systems, and 2) "no-till," which involves planting directly into untilled soil (Pollard et al., 1979).

iii. Other techniques, which the above tillage methods may be combined with, can reduce nutrient export further. These methods are 1) contour planting, and 2) terracing (Alberts et al., 1978).

d. Crop Types

i. Row crops (corn, soybeans etc.): Farmland planted with this type of crop is subject to channelization and erosion. Export of nutrients from watersheds consisting of row crops will be much higher than export from non row crop watersheds.

ii. Non row crops (wheat, millet, rye and other small grains): Growth of these crops does not generally lead to channelization. Therefore lower levels of nutrient export may be expected.

3. Agricultural Land Use: Pasture and Grazing Land

Nutrient export from these watersheds depends upon the method of management of the cattle, sheep, etc. and not necessarily on the volume of waste produced.

a. Rotational Grazing: Cattle are grazed on a particular piece of land for a limited time period (e.g., summer only). This allows vegetation to regrow which reduces runoff (including nutrient export).

b. Continuous Grazing: This results in 1) increases in soil compaction, 2) decreases in vegetation, and 3) increases in waste loads (manure). Therefore, nutrient export is usually high (Menzel et al., 1978).

c. Fertilization: Pastured watersheds are often fertilized to increase forage vegetation. This often increases the total amount of nutrient export (Olness et al., 1980).

d. Animal Density: Studies indicate that the greater the number of animals per unit area, the higher the amount of animal waste and the greater the potential for high nutrient export (Chichester et al., 1979).

4. Agricultural Land Use: Feedlot and Manure Storage

a. Percent Impervious Surfaces: If the percent of paved surfaces is high, the infiltration rate will be low and the runoff and nutrient export will be high (Coote and Hore, 1978).

b. Animal Concentration: If the animal density is high, the nutrient export can also be high (McCalla et al., 1972; Clarke et al., 1975).

c. Covered Feedlots: If the feedlot is inclosed with a roof, rainfall impact energy will be reduced, and runoff and nutrient export will be decreased (the higher the roof area/feedlot area ratio, the lower the runoff) (Dornbush and Madden, 1973; Coote and Hore, 1978).

d. Detention Basin: If a detention basin is present, nutrient export will be decreased (Coote and Hore, 1978).

5. Urban Land Use

Most urban runoff is channeled into storm drains, although not all storm drains serve a single watershed. Therefore, the output from a storm drain may consist of material from portions of one or more watersheds. It is important to determine the extent of the drainage system (if storm drains are used) in order to get an accurate estimate of areal nutrient loading.

Urban land uses consist of a number of sub uses, each with different features.

a. Characteristics of residential areas important to nutrient loading include: 1) housing density; 2) grass and vegetation coverage; 3) fertilizer applications; and 4) pet density, type (dogs, cats), etc. These characteristics are important because grass and housing density affect the infiltration/runoff ratio, while fertilizers and pets deposit nutrients in the watershed. Decreases in grass cover and increases in the other three increase nutrient export.

b. Public parks or park-like settings (campuses, research parks, etc.) have more vegetation (lawns, trees, ponds, etc.) than do commercial districts. Therefore, they can produce less runoff and nutrient export than do commercial districts.

c. Commercial/business/industrial areas have considerable street/pedestrian traffic. Thus there is more dust suspension, more contaminants from auto and industrial emissions, and more imprevious surfaces than in residential areas. Therefore, higher nutrient storm runoff often results.

6. Atmosphere

Atmospheric inputs consist of two major components: 1) wind transported material, commonly called dustfall, removed from the air by sedimentation or impaction; and 2) soluble gases or salts which are scavenged by rainfall. It is important when determining the magnitude of atmospheric loads to consider both of these components. Estimates for the dryfall portion alone may be as high as 70 - 90% of the total load (Heany and Sullivan, 1971; Likens and Loucks, 1978; Swank and Henderson, 1976; Miklas et al., 1977). In addition, the size of the dryfall fraction is generally considered to be independent of the amount of wetfall precipitation (Swank and Henderson, 1976; Delumyea and Petel, 1977; Eisenreich et al., 1977).

The sources of air-borne nutrients are not necessarily limited by the actual watershed boundary. That is, a lake's atmospheric input can be a result of cultural practices occurring in neighboring watersheds. However, the impact of atmospheric sources diminishes with distance.

a. In agricultural areas, increases in nutrient loads transported via the atmosphere can be attributed to agrarian activities and associated soil disturbances. These include:
   i. ammonia volatilization from feedlots and fertilizers,
   ii. wind erosion of fertilized soils.

   In addition, peak inputs of nutrients from the atmosphere tend to occur in late spring and early fall, in a pattern that roughly corresponds to fertilization and tilling periods (Andren et al., 1977; Delumyea and Petel, 1977; Eisenreich et al., 1977; Miklas et al., 1977; Hoeft et al., 1972).

b. Urban atmospheric inputs of nutrients can also be higher than those from forests. These increases can be attributed primarily to combustion emissions, since:
   i. Aviation and automotive fuels are known to contain organophosphorus additives to reduce corrosion (Simpson and Hemens, 1979).,
   ii. Fly ash from oil-fired boilers has been estimated to contain 0.9% phosphorus as P_2O_5, and open-hearth furnaces have been found to contain up to 0.3% phosphorus pentoxide (Delumyea and Petel, 1977),
   iii. Automotive emissions are believed to be the major source of NO_x, (Robinson and Robins, 1970), and
   iv. Photo-oxidation and hydrolysis reactions in an atmosphere containing hydrocarbons and oxides of nitrogen apparently are a major source of nitrites, nitrates and nitric acid in precipitation (Likens, 1972; Likens et al., 1977).

7. Septic Tanks and Soil Adsorption Fields

a. On-site septic tank-tile filed systems are another "non-point" source that must be considered because these systems are not always effective in trapping nutrients and preventing them from entering a waterway via groundwater transport. Three major waste fractions typically compose the septic tank receiving water. These are: 1) garbage disposal wastes; 2) toilet wastes, referred to collectively as black water; and 3) sink, basin and appliance wastewater collectively referred to as gray water (Siegrist et al., 1976, Bennett and Linstedt, 1975; Ligman et al., 1974; Olsson et al., 1968; Wallman and Cohen, 1974; Laak, 1975; Siegrist, 1977). Each waste fraction contributes comparable amounts of nutrients.

   i. Phosphorus in septic tank effluent originates from two main sources, human excreta and phosphate detergents.

   ii. Major sources of nitrogen (up to 80%) are feces and urine, with the predominant forms occurring as NH_4 and organic-N.

b. The mass loading of each nutrient to the septic system may depend on a number of considerations, and per capita-year loading coefficients presented in Table 14 should be chosen accordingly. These considerations include:

   i. Fraction of the year that the system is in use and the number of people using this form of waste disposal (i.e., summer cottage or year-round dwelling).

   ii. Amount of detergent used and the detergent phosphorus content. Phosphorus detergent bans will substantially reduce the total load since gray water phosphorus loads are high. Sawyer (1965) estimated that detergent - based phosphorus accounts for approximately 50 - 75% of the total phosphorus in domestic wastewater.

iii. Use of waste flow reduction methods. Siegrist (1977) estimates that several devices and systems such as low volume flush toilets, no-water toilets, wastewater recycle for toilet flushing, and suds-saver clotheswashers should produce waste flow reductions of up to 35%. This could significantly lower the concentration and/or pollutant mass in the household wastewater stream.

c. The estimated nutrient loading from septic systems to lakes will depend upon the location of the system with respect to the surface water body. The hypothesized "impacting zone" should include those systems within the watershed that contribute nutrients directly to a lake. For example, Rodiek (1979) developed a phosphorus budget for Lobdell Lake in Michigan and chose to use a 100 meter wide impact zone around the lake. Tributaries to the lake should also be included if certain conditions exist. These conditions include population distribution and other factors related to soil retention such as:

i. Phosphorus adsorption capacity: Relative phosphorus adsorption categories have been proposed by Schneider and Erickson (1972) and are outlined below:

Rate classes	Kilograms of phosphorus per hectare in top .9 meters
Very low	Less than 1120 Kg per hectare
Low	1120 to 1460 Kg per hectare
Medium	1460 to 1800 Kg per hectare
High	1800 to 2240 Kg per hectare
Very high	Over 2240 Kg per hectare

The percentage of phosphorus adsorbed is highly dependent on soil type and pH. Tofflemire and Chen (1977) proposed a procedure for the evaluation of soil retention of phosphorus. They examined several New York soils and found that, as a rule, for phosphorus removal, acid soils are better than calcareous, tills are better than outwashes, and clay soils are better than sandy soils.

ii. Soil drainage: Natural soil drainage is generally related to the depth of the water table. For septic system suitability, it is essential that a zone of aeration exist between the septic tile field and the water table at all times of the year. This zone functions as a chemical and physical filter for phosphorus (Ellis and Childs, 1973). For nutrient retention, well-drained to moderately well-drained soils are preferable because these conditions tend to lower the risk of nutrient contamination of groundwater. In other words, the greater the distance between the septic-tile field and the water table, the greater the likelihood that phosphorus will be immobilized and not transported to a surface water body via groundwater.

iii. Soil permeability: Permeability is the rate at which water is transmitted through saturated soil. This transmission rate is generally a function of soil texture and structure (i.e., the proportion of sand, silt and clay). High rates of water transmission are usually indicative of sandy soils, while low rates are usually associated with clay soils, soils possessing a clay lens, or an impervious layer at or near the ground surface. Relative classes of soil permeability can be used to describe conditions of water transmission. Schneider and Erickson (1972) propose the following classes of soil permeability.

Rate classes	Permeability rate in centimeters per hour
Very slow	< .50
Slow	.50 - 2.00
Moderate	2.00 - 6.40
Rapid	6.40 - 25.40
Very rapid	> 25.40

Soils having a moderate rate of permeability are optimal in terms of septic system operation since these rates are slow enough for phosphorus adsorption reactions to occur, yet fast enough to avoid system "back-up" that results in standing effluent.

iv. Groundwater movement: In addition to the above three factors, both direction and flow rate for groundwater must be considered. The presence of clay lenses or bedrock can substantially reduce groundwater flows to a lake, and in some situations flow can be redirected from the lake altogether (to subterranean reservoirs or to another watershed).

v. Slope: Steep slopes and low permeability rates may cause erosion problems and perhaps convert the septic tank effluent to overland runoff. In soils of good drainage and high permeability, gravitational forces hasten groundwater flow (and nutrient transport to surface water bodies).

vi. System age: Soils have only a finite capacity for phosphorus adsorption. Old systems may provide less soil retention of phosphorus than do new systems.

vii. Plant uptake: The presence of a "green strip" of vegetation consisting of shrubs, bushes, trees, etc., between the septic tank-tile field and the waterbody can effectively reduce the amount of phosphorus entering a lake. This will depend, in part, on vegetation type and density.

viii. Season: High rainfall seasons, such as spring or late summer, keep the soil saturated, thereby decreasing soil phosphorus adsorption capacity.

ix. Other: Factors such as frequency of cleaning (of both septic tank and drainfield) and the effluent-soil redox potential should also be considered.

8. Sewage Treatment Plants

Wastewater treatment plants are another phosphorus source that have been studied to some degree. As a result, data do exist for the estimation of phosphorus loads and variability. Among the issues that should be considered by the analyst attempting to use these loading coefficients (Table 15) are:

a. Type of plant: Plant type, or more appropriately, the type of treatment the plant is using, will determine to a great extent how much phosphorus will be contined in the effluent. Different treatment types provide different levels of phosphorus reduction in the waste stream. Obviously, those plants using phosphorus removal will have lower per capita phosphorus outputs than those that do not.

b. Separate or combined sewerage systems: Wastewater treatment facilities have a finite capacity to treat sewage inputs. Under normal circumstances, treatment capacity is closely related to the extent of the sewerage system. If the system is composed of both storm and sewage drains, treatment capacity if overtaxed during high rainfall events, and a portion of the combined inputs are short circuited through to the outfall. Final mass loads of phosphorus can be appreciably higher when this occurs.

c. Phosphate detergent ban: If phosphorus inputs are reduced, (i.e., through a ban on phosphate detergent additives), the final per capita mass load will also be lower. From a study of 702 wastewater treatment plants with a variety of treatments processes employed, Allum et al., (1977), estimated a median phosphorus loading of 1.0 ± 0.04 kg/capita/yr. However, for Indiana, with a full-year phosphate detergent ban, this median figure was found to be 0.5 ± 0.11 kg/capita/yr (25 plants). New York, with about a one-half year phosphate detergent ban, fell between the two with a median phosphorus discharge of 0.7 ± 0.11 kg/capita/yr (42 plants).

In concluding this section on guidelines for export coefficient selection, some comments on watershed size, proximity to the application lake, and bioavailability are in order. It should be noted that small watersheds, such as microplots (<0.5 hectares), provide less opportunity for redeposition of suspended sediment (and nutrients) than do large watersheds. Even though the "100-year" storm will scour considerable amounts of deposited nutrients from streambeds--thus balancing any loading inequalities between large and small basins--some investigators feel that in the short term, small runoff plots or small watersheds tend to overestimate the mass of nutrients removed by surface runoff.

In addition, Schuman et al., (1973) demonstrated that water samples for all runoff events taken adjacent to the outflow of an agricultural watershed contained considerably more inorganic phosphorus in solution than did samples taken

70-230 meters downstream. This reduction in solution phosphorus was attributed to the adsorption of phosphorus by the additional suspended soil material entering the stream from gully erosion. This decrease in solution phosphorus in the runoff was accompanied by an increase in phosphorus on the sediment transported. Thus total phosphorus loss measured at the two sites agreed relatively well. Studies by Meyer and Likens (1979) at Bear Brook (an undisturbed headwater stream in the Hubbard Brook Experimental Forest, New Hampshire) indicate that there was a net conversion of dissolved phosphorus and course particulate phosphorus (leaves, organic fragments, etc.) to the fine particulate fraction, which was the predominant form (62% of the total) exported downstream.

Therefore, small plots (from which many of the export coefficients presented in Chapter 3 and in the Appendix are based) are likely to yield high export values for certain situations. These values will consist of both high solution fractions and high sediment fractions. These fractions will tend to be higher than those reported for larger watersheds (several hectares in size). Thus, small watershed export coefficients are most applicable to application lake watershed sections adjacent to a surface water body (tributary streams or the lake). This means, of course, that watershed size is an important watershed matching criterion.

For large basins consisting of mixed agricultural activities, export coefficients from the tables entitled "Mixed Agriculture" should be used. Individual assignment of export coefficient according to each use may result in an overly high total loading estimate due to the small watershed bias mentioned above.

Bioavilability is another concern. In general, the more solution phosphorus converted to sediment phosphorus, the lower the bioavilable fraction. However, since the models are based on total phosphorus, bioavailability cannot be incorporated into the Chapter 2 methodology. If it is thought that an unusually large fraction of the phosphorus loading to a lake is not biologically available, then the analyst should note this and be aware of possible model prediction bias.

3.4 The Phosphorus and Nitrogen Export Coefficients

1. Summary Tables - Text To facilitate the analyst's ability to use the model and quantitative approach presented in this manual, nutrient loading coefficients from overland runoff were identified in an extensive literature search (Beaulac, 1980). While the emphasis of this report is on phosphorus management and modeling, for comparison purposes, export coefficients are also given for nitrogen. Those studies which conform to the sampling criteria discussed in earlier sections of this chapter have been aggregated by land use and are presented in tabular fashion in Tables 6 through 12. The major land uses examined are undisturbed forests, agriculture and urban.

   As previously discussed, the range of nutrient export from forest land use is relatively narrow. Climate (i.e., precipitation and runoff) and productivity appear to be the major criteria determining nutrient export variability. The analyst is therefore urged to extrapolate only those coefficients originating from climatic conditions and regions similar to the application watershed. For comparison, vegetation type, soil type, location, precipitation and runoff amount have been tabulated along with the export coefficient and reference in Table 6.

Agricultural land uses consist of a number of different perturbations, and sufficient studies exist in the literature to describe these activities. Therefore, this land use was further subdivided into row crops, non-row crops, pasture/grazing land, and manure storage/animal feedlot. The loading coefficients are presented in Tables 7 through 10 respectively. For comparison purposes, and to allow for estimation of nutrient export from highly mixed agricultural watersheds, export coefficients were compiled for general (mixed) agricultural activities in Table 11. In addition to the descriptive conditions listed in the forest export tables, fertilization rate and crop type(s) have also been included.

The coefficients describing urban land uses also exhibit a high degree of variability depending primarily on the type of urban activity (i.e., low density residential, heavy industrial) and the associated percentage of impervious surface area. Unfortunately, sufficient data do not currently exist in the literature to adequately compile summary tables for each of these activities. Therefore, the analyst is urged to pay particular attention to the accompanying descriptive criteria listed in Table 12.

2. Summary Tables - Appendix To provide the reader with a more complete record of the variability and magnitude of the chemical fractions composing both phosphorus and nitrogen (i.e., sediment phosphorus, NO_3-N), a breakdown of these chemical fractions is included in the Appendix. The tables in the Appendix include all "approved" nutrient runoff coefficients presented in the text plus some information from studies which did not focus on total nutrient loads. To reduce repetition,

most of the watershed characteristics have been eliminated if the particular study was adequately described in the text tables.

3. Histograms The effects of watershed characteristics and climatic conditions on nutrient export can be observed from a study of the loading coefficients in the above tables. However, this variability can be more properly assessed through examination of the data in frequency distributions or histograms. Accordingly, histograms describing nutrient export from the above land uses have been developed and are presented in Figures 4 through 10.

From the histograms it is apparent that the cross-sectional data are highly skewed. Consequently, robust statistics such as the median and interquartile range are generally less biased as summary statistics than are the mean and standard deviation. These statistics accompany the histograms for each land use.

The histograms allow the analyst to note the cross-sectional variability resulting from different characteristics among watersheds that determine nutrient export. As an example the reader is referred to Figure 7a, representing phosphorus export from pastured and grazed watersheds. The values on the left represent phosphorus export from those watersheds grazed primarily in summer or on a rotational basis, while those on the right represent export from watersheds with either continuous grazing or forage fertilization. This cause-effect relationship emphasizes the need for proper examination and selection of the coefficients for extrapolation purposes.

Cross-sectional variability among watersheds must be distinguished from longitudinal variability. Longitudinal, or time series, variability represents the variation in nutrient export in a single watershed over time. To illustrate longitudinal variability, phosphorus exports from two similar adjacent corn cropped watersheds, one with seven years of identical fertilization rates and the other with five, were combined to create the histogram in Figure 11. Since variation in precipitation runoff is the probable key cause of longitudinal variablity, a histogram of water runoff rates was also developed and presented in Figure 12. Note the high degree of similarity between the two distributions.

4. <u>Box Plots</u> A useful graphical technique for displaying batches of data is the box plot. This technique is based on order statistics (ordering the data points from low to high value) and the plot itself is constructed from five values from the (ordered) data set. These values are: 1) the median; 2) the minimum value; 3) the maximum value; 4) the 25 percentile value; and 5) the 75 percentile value (see Figure 2).

   Visual comparisons of box plots may be enhanced by the incorporation of the statistical significance of the median into the plot. This is achieved by notching the box at a desired confidence level. For example, if the 95% confidence level notches around two medians do not overlap in the display, the medians are roughly significantly different at the 95% confidence level (see McGill et al., 1978; and Reckhow, 1980 for details on confidence limits and other aspects of box-plot construction).

   In addition to the above information, the box plots can include the following (Reckhow, 1980):

   1. the interquartile range;
   2. the sample range;
   3. an indication of skew (from a comparison of the symmetry above and below the median); and
   4. the size of the data set.

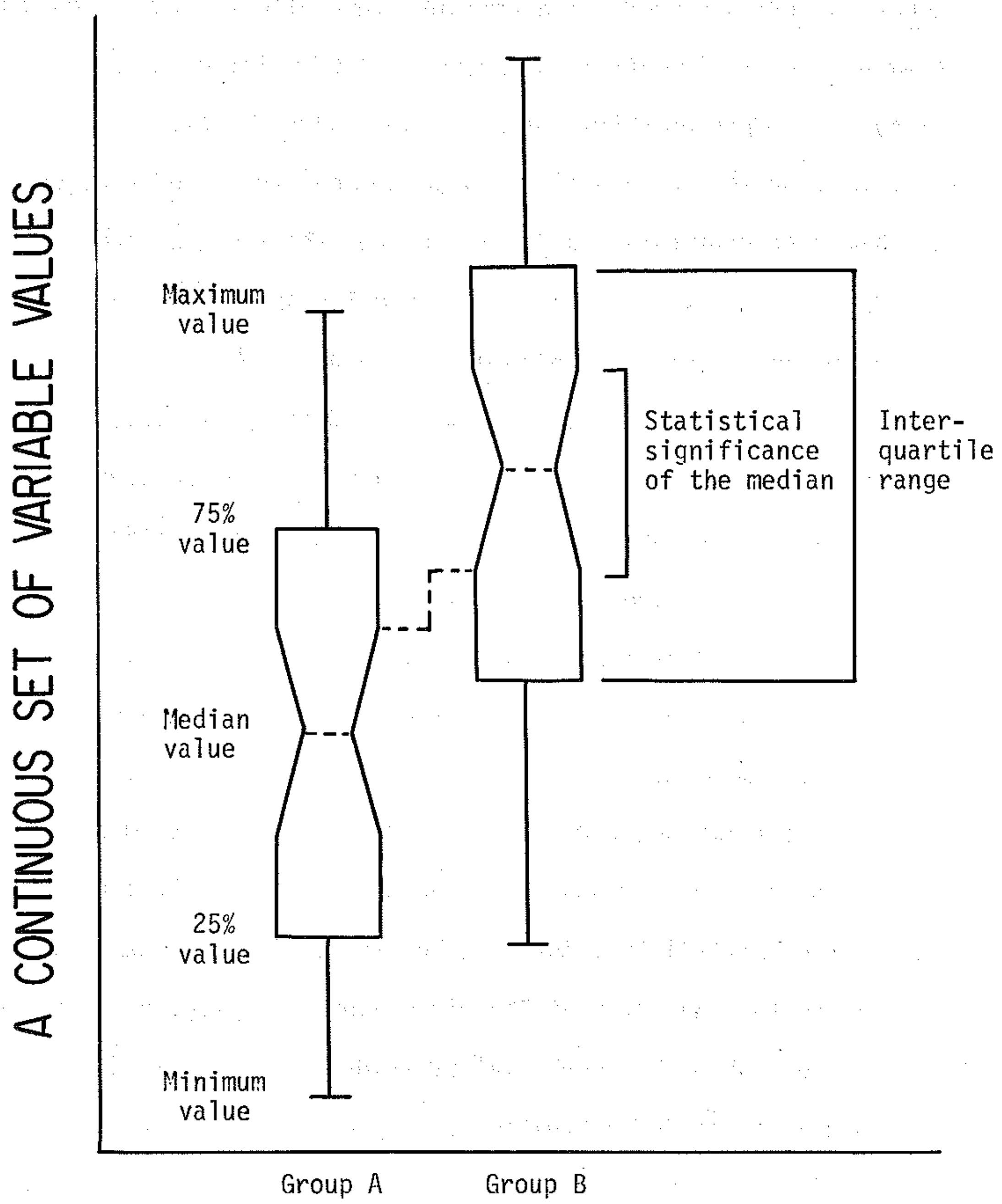


Figure 2: The Basic Configuration of a Box Plot and Comparison of Two Plots Possessing Significantly Different Medians

Note that the box plot medians for forested phosphorus and nitrogen export (Figure 3) are significantly different from those of agriculture and urban land runoff (with the exception of pasture land).

5. Other Tables In addition to the thorough examinaton of the literature on nutrient runoff from forest, agriculture, and urban land use activities, other non-point and point nutrient loading information was compiled in tabular form for this document.

   a. Atmospheric Inputs: Uttormark et al., 1974, listed at least 40 factors influencing atmospheric nutrient contributions. The bulk of these factors are related to local conditions. Therefore, a literature review was conducted to collect data relating bulk nutrient precipitation inputs to specific land uses. A major requirement for data acceptability was that the nutrient inputs be collected from one of three land uses: 1) undisturbed-forest; 2) agricultural-rural; and 3) urban-industrial. Studies dealing with regional or cross-sectional watersheds were thereby disregarded. In this respect, precipitation chemistry may more closely reflect endemic situations. These nutrient coefficients are presented in Table 13.

   b. Septic Tank Inputs: Information was collected to define a range of values for the nutrient load in household wastewater discharged into septic tanks. Since the values expressed in Table 14 are not quantified according to the number of sources contributing to the total load (i.e., percent contributed by gray water vs. black water), it is recommended that the reader examine the section dealing with septic tanks in order to justify the selection of the export coefficient.

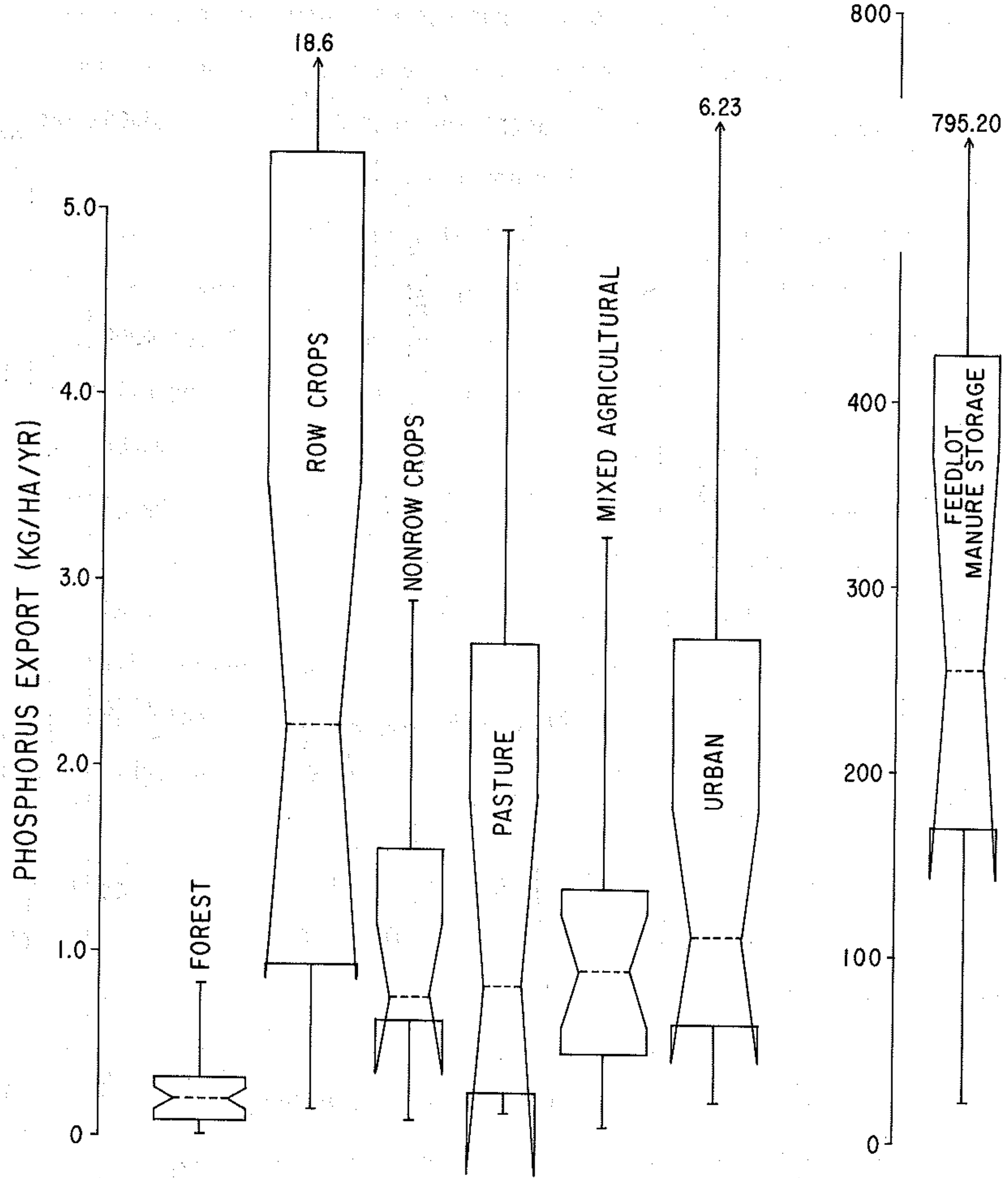


Figure 3a: Box Plots of Phosphorus Export Coefficients from Various Land Uses.

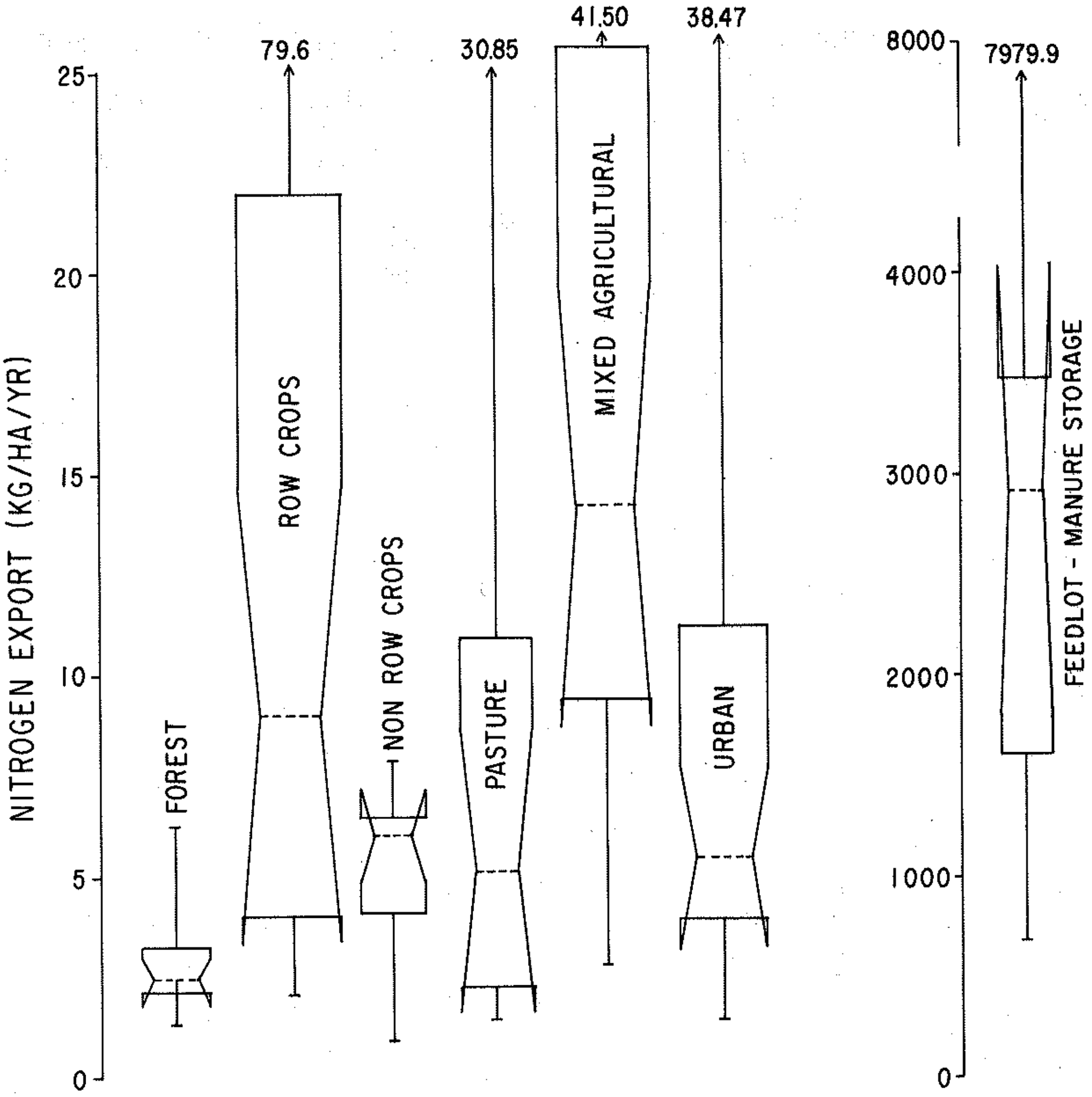


Figure 3b: Box Plots of Nitrogen Export Coefficients from Various Land Uses.

c. Sewage Treatment Plant Inputs: The data set compiled by the EPA-NES (1974) listing statewide sewage treatment plant phosphorus loads was summarized according to treatment type in Table 15. As previously discussed in earlier sections, a number of factors can increase or reduce the coefficients presented. This may be verified from an examination of the ranges given for each treatment type. It is further stressed that the analyst examine the actual conditions within the study watershed before the selection of these coefficients is made.

Table 6: Nutrient Export from Forested Watersheds

Land Use	Location	Soil Type/Texture	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
75-100 year old jack pine & black spruce, with birch & trembling aspen (342.1 ha)	Kenora Experimental Watershed Rawson Lake Ontario, Canada	medium-fine silicate sand overlying deeper deposits containing some clay fractions	77.3^a (70.1 - 96.7)	26.55^a (22.3 - 35.4)	6.26^a (5.69 - 7.32)	$.309^a$ (.220 - .435)	Schindler et al., 1976
Climax hardwoods maple, beech, red oak, with yellow birch and hemlock (125 ha)	Clear Lake Watershed Haliburton County, Ontario, Canada		126.3	68.00		.090	Schindler and Nighswander, 1970
Jack pine - black spruce	Northwest Ontario, Canada	sandy loam			2.37^b	$.060^b$	Nicholson, 1977
Jack pine - black spruce	Northwest Ontario, Canada	sandy loam			1.38^b	$.036^b$	Nicholson, 1977
Mixed deciduous forest	Southern Ontario, Canada	sandy soils overlying granitic igneous formation				$.047^c$ (.025 - .077)	Dillon and Kirchner, 1975
Mixed deciduous forest	Southern Ontario, Canada	loam soils overlying sedimentary formation				$.107^d$ (.067 - .145)	Dillon and Kirchner, 1975
Mixed deciduous forest (.01 ha)	Lake Minnetonka Watershed, Minnesota	loam, silt loam, clay loam	129.0	84.3		.090	Singer and Rust, 1975
70% aspen 30% black spruce and alder (10 ha)	Marcell Experimental Forest, Minnesota	70% loam, clay & sands 30% organic peats		17.70^e (15.5 - 19.2)	2.26^e (1.74 - 2.37)	$.157^e$ (.124 - .179)	Verry, 1979
Aspen - birch forest (6.48 ha)	Marcell Experimental Forest, Minnesota	loam, clay and sands	79.48^e (75.51 - 82.10)	15.56^e (13.73 - 21.47)	2.46^e (1.92 - 3.29)	$.280^e$ (.19 - .38)	Timmons et al., 1977

Table 6: (continued)

Land Use	Location	Soil Type/Texture	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
Maple, birch and beech (15.6 ha)	Watershed #6 Hubbard Brook Experimental Forest, New Hampshire	sandy loam	132.2^{f}	83.30^{f}	4.01^{f}	$.019^{f}$	Likens et al., 1977
Deciduous hardwood and pine (17.6 ha)	Coshocton, Ohio	silt loam	88.9^{e} (85.4 - 95.8)	32.00^{e} (25.3 - 35.6)	2.82^{e} (1.37 - 3.16)	$.035^{e}$ (.0349 - .0722)	Taylor et al., 1971
Oak-hickory forest (97.5 ha)	Walker Branch Watershed, Oak Ridge, Tennessee		136^{g}	70.70^{g}	3.1^{g}		Henderson and Harris, 1973
Oak-hickory forest (97.5 ha)	Walker Branch Watershed, Oak Ridge, Tennessee		157.1^{a} (128.2 - 187.5)	94.65^{a} (71.0 - 116.1)	2.0^{g} (1.7 - 2.2)	$.025^{a}$ (.010 - .030)	Henderson et al., 1977
Oak maple yellow poplar, black cherry, beech (34 ha)	Fenrow Experimental Forest, Parsons, West Virginia	silt loam				$.140^{e}$ (.040 - .180)	Aubertin and Patric, 1974
Mixed pine and hardwood (40 ha)	Eatonton, Georgia		164.0	48.70		0.275	Krebs and Golley, 1977
Mixed pine and hardwood	Rhode River Watershed, Maryland				1.50	0.200	Correll et al., 1977
99% mixed forest 1% developed (6495 ha)	Woodlands, Texas	clays		7.30		0.212	Bedient et al., 1978
Loblolly and slash pine	Copperville, Mississippi	loess over sedimentary deposits					Duffy et al., 1978
2.81 ha			205.0	36.90		0.281	
1.93 ha			205.0	38.95		0.306	
2.39 ha			205.0	34.85		0.357	
1.64 ha			205.0	30.75		0.321	
1.49 ha			205.0	22.55		0.226	

Table 6: (continued)

Land Use	Location	Soil Type/Texture	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
Douglas fir and western hemlock (47139.5 ha)	Yakima River, Western Cascade Range, Washington				3.32	0.830	Sylvester, 1960
Douglas fir and western hemlock (32376 ha)	Cedar River, Western Cascade Range, Washington					0.360	Sylvester, 1960
Douglas fir and western hemlock (10.1 ha)	H. J. Andrews Experimental Forest, Western Cascade Range, Oregon		215.0	135.0		0.520	Fredriksen, 1972
Douglas fir and western hemlock	Fox Creek, Western Oregon	silt & clay loams		158.0		0.180	Fredriksen, 1979
Douglas fir and western hemlock	Coyote Creek, Western Oregon	silt & clay loams		76.0		0.680	Fredriksen, 1979

a. Four year median
b. Four year mean from twelve watersheds
c. Two year median from twenty watersheds
d. Two year median from four watersheds
e. Three year median
f. Twelve year mean
g. Two year mean

Table 7: Nutrient Export from Row Crops

Land Use	Fertilizer Application kg/ha/yr N	P	K	Location	Soil Type/Texture	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
Corn (.004 ha)	0	0	0	Lancaster, Wisconsin	silt loam	77.0^{a} (65.76 - 77.6)	10.7^{a} (8.51 - 21.95)	3.96^{a} (3.61 - 5.53)	1.22^{a} (1.22 - 1.49)	Minshall et al., 1970
Corn; fresh manure applied in winter (.004 ha)	109	39	99	Lancaster Winconsin	silt loam	77.0^{a} (65.76 - 77.6)	12.26^{a} (5.97 - 19.41)	7.97^{a} (3.05 - 26.88)	2.00^{a} (1.03 - 5.77)	Minshall et al., 1970
Corn; fermented manure applied in spring (.004 ha)	102	44	85	Lancaster, Wisconsin	silt loam	77.0^{a} (65.76 - 77.6)	11.51^{a} (5.59 - 15.32)	3.38^{a} (3.35 - 5.32)	.75^{a} (.68 - .96)	Minshall et al., 1970
Corn; liquid manure applied in spring (.004 ha)	78	33	114	Lancaster, Wisconsin	silt loam	77.0^{a} (65.76 - 77.6)	12.45^{a} (5.61 - 15.60)	2.88^{a} (2.81 - 5.07)	.95^{a} (.76 - 1.18)	Minshall et al., 1970
Corn (.004 ha)	0	0	0	Wisconsin	silt loam		11.52^{b} (8.71 - 14.33)	4.33^{b} (4.08 - 4.58)	1.30^{b} (1.00 - 1.60)	Hensler et al., 1970
Corn; fresh manure applied in winter (.004 ha)	108	39	99	Wisconsin	silt loam		9.32^{b} (7.11 - 11.53)	15.25^{b} (4.44 - 26.06)	3.40^{b} (1.13 - 5.66)	Hensler et al., 1970
Corn; fermented manure applied in spring (.004 ha)	108	34	99	Wisconsin	silt loam		8.81^{b} (7.11 - 10.52)	4.22^{b} (3.68 - 4.76)	.81^{b} (.73 - .90)	Hensler et al., 1970
Corn; liquid manure applied in spring (.004 ha)	108	39	99	Wisconsin	silt loam		9.45^{b} (8.10 - 10.79)	3.88^{b} (3.70 - 4.07)	.94^{b} (.91 - .97)	Hensler et al., 1970
Corn (.009 ha)	112	29		Morris, Minnesota	loam	62.6^{c}	8.6^{c}	79.6^{c}	18.6^{c}	Young and Holt, 1977
Corn (.009 ha)	29	81		Morris, Minnesota	loam	65.7^{d}	10.1^{d}	44.2^{d}	14.0^{d}	Young and Holt, 1977

Table 7: (continued)

Land Use	Fertilizer Application kg/ha/yr N P K	Location	Soil Type/Texture	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
Corn; surface spread manure (.009 ha)	29 81 plus 239 43 from manure	Morris, Minnesota	loam	65.7^{d}	3.8^{d}	27.9^{d}	8.6^{d}	Young and Holt, 1977
Corn; plowdown manure (.009 ha)	29 81 plus 239 42 from manure	Morris, Minnesota	loam	65.7^{d}	4.0^{d}	33.0^{d}	9.8^{d}	Young and Holt, 1977
Corn (.009 ha)	56 29	Morris, Minnesota	loam	57.2^{e}	4.57^{e}	14.24^{e}	3.14^{e}	Burwell et al., 1975
Corn (.009 ha)	112 29	Morris, Minnesota	loam	57.2^{e}	8.03^{e}	23.63^{e}	5.55^{e}	Burwell et al., 1975
Corn; contour planting (30 ha)	448 64	Treynor, Iowa	deep loess, fine, silty mixed mesics	79.79^{f} (63.07 - 105.95)	5.47^{f} (1.37 - 12.57)	8.69^{f} (2.2 - 72.47)	.59^{f} (.092 - 2.118)	Alberts et al., 1978
Corn; contour planting (33.6 ha)	168 39	Treynor, Iowa	deep loess, fine, silty mixed mesics	78.65^{f} (62.16 - 104.59)	3.86^{f} (1.52 - 9.76)	5.36^{f} (1.69 - 43.71)	.35^{f} (.083 - 1.288)	Alberts et al., 1978
Corn; contour planting (60 ha)	280 64	Treynor, Iowa	deep loess, fine, silty mixed mesics	73.76^{f} (52.8 - 102.5)	1.75^{f} (.35 - 10.71)	2.1^{f} (.67 - 26.7)	.26^{f} (.024 - .613)	Alberts et al., 1978
Corn (1.29 ha)	284 54	Watkinville, Georgia	sandy loam-sandy clay loam	107.7	13.0	12.42	2.21	Smith et al., 1978
Corn (.001 ha)	100 35 35	Northern, Alabama	silt loam	87.39		3.29	.40	Bradford, 1974
Soybeans; two crops/yr; conventional tillage (.01 ha)	0 29 56	Holly Springs, Mississippi	silt loam	143.75^{b}	55.75^{b}	46.50^{b}	17.64^{b}	McDowell et al., 1978

Table 7: (continued)

Land Use	Fertilizer Application kg/ha/yr N	P	K	Location	Soil Type/Texture	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
Soybeans; two crops/yr; no till (.01 ha)	0	29	56	Holly Springs, Mississippi	silt loam	143.75^{b}	27.9^{b}	5.1^{b}	2.6^{b}	McDowell et al., 1978
Cotton (17.9 ha)	33	25	24	Chickasha, Oklahoma	silt loam	81.3^{g} (72.7 - 97.3)	13.1^{g} (8.8 - 24.1)	9.31^{g} (4.99 - 11.49)	4.31^{g} (2.38 - 11.52)	Menzel et al., 1978
Cotton (12.1 ha)	33	25	24	Chickasha, Oklahoma	silt loam	80.7^{g} (72.9 - 96.3)	12.7^{g} (8.0 - 24.8)	11.16^{g} (5.18 - 14.84)	4.58^{g} (2.07 - 10.75)	Menzel et al., 1978
Soybeans - Corn two crops/yr no till (.01 ha)	0	29	56	Northern, Mississippi	silt loam	143.8	54.9	23.0	7.2	McDowell et al., 1978
Corn - Soybeans two crops/yr no till (.01 ha)	136	20	37	Northern, Mississippi	silt loam	143.8	50.5	19.3	3.7	McDowell et al., 1978
Tobacco and Corn	85	40		Rhode River Watershed, Maryland	fine sandy, loam	114.7		3.7	1.4	Correll et al., 1977

a. Three year median
b. Two year mean
c. Ten year mean
d. Three year mean
e. Six year mean
f. Seven year median
g. Four year median

Table 8: Nutrient Export from Non Row Corps

Land Use	Fertilizer Application kg/ha/yr			Location	Soil Type/Texture	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
	N	P	K							
Alfalfa (.004 ha)	0	0	0	Madison, Wisconsin	silt loam	107.8^a (105.4 - 108.8)	14.2^a (8.2 - 18.5)	6.28^a (5.66 - 14.67)	$.76^a$ (.75 - 2.40)	Converse et al., 1976
Alfalfa; fall applied manure (.004 ha)	121	24	100	Madison, Wisconsin	silt loam	107.8^a (105.4 - 108.8)	7.8^a (5.2 - 9.0)	6.63^a (6.10 - 23.09)	1.24^a (1.20 - 8.08)	Converse et al., 1976
Alfalfa; winter applied manure (.004 ha)	121	24	100	Madison, Wisconsin	silt loam	107.8^a (105.4 - 108.8)	10.3^a (8.2 - 12.8)	7.82^a (5.88 - 38.22)	$.64^a$ (.58 - 6.09)	Converse et al., 1976
Alfalfa; spring applied manure (.004 ha)	121	24	100	Madison, Wisconsin	silt loam	107.8^a (105.4 - 108.8)	10.1^a (6.7 - 15.0)	6.43^a (4.07 - 11.42)	1.81^a (.55 - 2.39)	Converse et al., 1976
Alfalfa and Bromegrass two plots: 3.55 - 4.10 ha				Eastern South Dakota	sandy clay laom	57.9^b (50.0 - 65.7)	2.69^b	$.97^b$	$.10^b$	Harms et al., 1974
Wheat (5.2 ha)	45	7^c		Chickasha, Oklahoma	silt loam	80.4^d (72.9 - 96.5)	8.75^d (5.5 - 20.8)	5.88^d (3.77 - 7.12)	1.64^d (.80 - 3.34)	Menzel et al., 1978
Wheat (5.3 ha)	45	7^c		Chickasha, Oklahoma	silt loam	80.5^d (72.9 - 96.6)	7.4^d (5.4 - 23.0)	6.53^d (2.89 - 8.95)	1.56^d (.59 - 4.29)	Menzel et al., 1978
Spring wheat and summer stubble Two year rotation (4-5 ha)	0	0	0	Swift Current, Saskatchewan, Canada	loam		35.0^b (7.0 - 62.5)		$.35^b$ (.1 - .6)	Nicholaichuk and Read, 1978
Spring wheat and summerfallow (4-5 ha)	0	0	0	Swift Current, Saskatchewan, Canada	loam		58.5^b (19.0 - 98.0)		1.35^b (.4 - 2.3)	Nicholaichuk and Read, 1978
Spring wheat and fall fertilized summerfallow (4-5 ha)	50	54		Swift Current, Saskatchewan, Canada	loam		28.0^b (7.0 - 49.0)		2.9^b (.2 - 5.6)	Nicholaichuk and Read, 1978

Table 8: (continued)

Land Use	Fertilizer Application kg/ha/yr			Location	Soil Type/Texture	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
	N	P	K							
Millet (.001 ha)	100	35	35	Northern Alabama	silt loam	87.39		3.04	.44	Bradford, 1974
Oats (.009 ha)	18	30		Morris, Minnesota	loam	57.2[e]	6.89[e]	4.22[e]	.65[e]	Burwell et al., 1975
Hay (.009 ha)	0	0	0	Morris, Minnesota	loam	57.2[e]	14.2[e]	4.09[e]	.64[e]	Burwell et al., 1975

a. Three year median
b. Two year mean
c. Eleven year mean
d. Four year median
e. Six year mean

Table 9: Nutrient Export from Grazed and Pastured Watersheds

Land Use	Fertilizer Application kg/ha/yr N	P	K	Location	Soil Type/Texture	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
Moderate dairy grazing, bluegrass cover (1.88 ha)	37	16	8	Wayneville, North Carolina		106.1^a (104.3 - 119.8)	21.3^a (12.3 - 24.6)	3.46^a (2.41 - 3.83)	$.14^a$ (.12 - .16)	Kilmer et al., 1974
Heavy dairy grazing, bluegrass cover (1.48 ha)	149	64	12	Wayneville, North Carolina		106.1^a (104.3 - 119.8)	26.4^a (19.9 - 31.8)	10.99^a (8.31 - 18.05)	$.16^a$ (.11 - .70)	Kilmer et al., 1974
Pasture (6.28 ha)				Eastern South Dakota	sandy clay loam	58.4	4.44	1.52	.25	Harms et al., 1974
Winter grazed and summer rotational, orchardgrass and bluegrass cover (1 ha)	56	0	0	Coshocton, Ohio	silt loam	108.0	12.94	30.85	3.6	Chichester et al., 1979
Summer grazed (1 ha)	56	0	0	Coshocton, Ohio	silt loam	108.0	2.92	21.35	$.85^b$	Chichester et al., 1979
Rotation grazing (42.9 ha)	168	39		Treynor, Iowa	silt loam	75.44^c (73.3 - 77.83)	3.86^c (.94 - 4.39)	2.32^c (.47 - 4.28)	$.251^c$ (.081 - .512)	Schuman et al., 1973 a, b
Pasture for brood cattle (10 ha)	0	0	0	Eatonton, Georgia		164.0	61.8		1.35	Krebs and Golley, 1977
Continuous grazing with some supplementary winter feeding; some hay production (351.2 ha)				Rhode River Watershed, Maryland	well drained, sandy loams	114.7		13.0	3.8	Correll et al., 1977
Continuous grazing, little bluestem cover, Active gullies (11.1 ha)	0	0	0	Chickasha, Oklahoma	silt loams	88.25^d (50.7 - 105)	15.1^d (2.02 - 28.4)	6.13^d (1.33 - 9.23)	1.46^d (.27 - 3.86)	Menzel et al., 1978

Table 9: (continued)

Land Use	Fertilizer Application kg/ha/yr			Location	Soil Type/Texture	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
	N	P	K							
Rotation grazing little bluestem cover; good cover (11.0 ha)	0	0	0	Chickasha, Oklahoma	silt loams	88.35[d] (52.4 - 109.1)	5.95[d] (.35 - 17.8)	1.48[d] (.15 - 2.3)	.25[d] (.02 - 1.44)	Menzel et al., 1978
Continuous grazing, little bluestem cover (7.8 ha)	83	72	0	Chickasha, Oklahoma	silt loam	76.5[e]	14.7	9.20	4.90	Olness et al., 1980
Rotational grazing, little bluestem cover (9.6 ha)	87	76	0	Chickasha, Oklahoma	silt loam	78.2[e]	4.3	4.72	3.09	Olness et al., 1980
Continuous grazing, little bluestem cover active gullies (11.1 ha)	0	0	0	Chickasha, Oklahoma	silt loam	76.5[e]	10.2	5.19	.76	Olness et al., 1980
Rotational grazing, little bluestem cover (11.0 ha)	0	0	0	Chickasha, Oklahoma	silt loam	78.2[e]	4.3	1.73	.20	Olness et al., 1980

a. Four year median; sediment phase not sufficiently examined
b. Major contribution from underground spring
c. Three year median
d. Four year median
e. Nine year mean

Table 10: Nutrient Export from Animal Feedlots and Manure Storage

Land Use	Location	Soil/Surface Characteristics	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
Beef livestock feedlot (4.76 ha)	Brookings, South Dakota	1/2 concrete 1/2 grassed	60.71^{a} (53.19 - 61.06)	21.87^{a} (8.92 - 28.52)		523.0^{a} (145.6 - 749.0)	Dornbush and Madden, 1973
Lamb feedlot (21.32 ha)	Brookings, South Dakota	includes detention pond	54.48^{b} (49.96 - 59.0)	2.07^{b} (1.96 - 2.18)		26.88^{b} (20.16 - 35.84)	Dornbush and Madden, 1973
Lamb feedlot (12.63 ha)	Brookings, South Dakota	includes detention storage culvert	49.96	3.10		21.28	Dornbush and Madden, 1973
Dairy confinement, 45 head of cattle (.13 ha)	Brookings, South Dakota	concrete plus roof runoff	58.01^{a} (48.16 - 62.53)	27.18^{a} (15.16 - 82.65)		355.0^{a} (301.3 - 521.9)	Dornbush and Madden, 1973
Beef and sheep feedlot (.603 ha)	Brookings, South Dakota	concrete surface	58.01^{a} (48.16 - 62.53)	15.24^{a} (14.40 - 30.35)		222.9^{a} (157.9 - 2635.4)	Dornbush and Madden, 1973
Beef feedlot, 300 head of cattle (1.6 ha)	Brookings South Dakota		59.74^{b} (55.83 - 63.73)	6.35^{b} (3.99 - 8.71)		86.2^{b} (29.1 - 142.2)	Dornbush and Madden, 1973
Beef cattle feedlot, 9.29 m^2/cow (.002 ha)	Mead, Nebraska	silty clay loam overlying sand		15.87^{b} (14.68 - 17.07)	2923.2^{b} (2016.0 - 3830.4)	795.2^{b} (291.2 - 1299.2)	McCalla et al., 1972
Beef cattle feedlot, 18.6 m^2/cow (.002 ha)	Mead, Nebraska	silty clay loam overlying sand		17.93^{b} (16.59 - 19.28)	1344^{b} (1254.4 - 1433.6)	347.2^{b} (224.0 - 470.4)	McCalla et al., 1972
Beef cattle feedlot, 18.6 m^2/cow (.002 ha)	Mead, Nebraska	silty clay loam overlying sand		24.94^{b} (24.59 - 25.3)	3584^{b} (1388.8 - 2195.2)	224^{b} (134.4 - 313.6)	Gilbertson et al., 1975
Beef cattle feedlot, 500 - 600 cattle (.25 ha)	Kent Co., Ontario, Canada	concrete	70.7	33.2	3372.27	425	Coote and Hore, 1978
Beef cattle feedlot (.17 ha)	Waterloo Co., Ontario, Canada	paved and unpaved	78.6	17.3	680.52	170	Coote and Hore, 1978

Table 10: (continued)

Land Use	Location	Soil/Surface Characteristics	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
Solid manure storage agea (.05 ha)	Elmira, Ontario, Canada	2/3 paves 1/3 unpaved	67.37	20.9	1891.07	172	Coote and Hore, 1978
Manure storage facility (.05 ha)	Burlington, Vermont	crushed limestone	57.7	33.5	7979.9	539.9	Magdoff et al., 1977

a. Three year median
b. Two year mean
c. Derived from original values of kg/cow/yr with permission of authors.

Table 11: Nutrient Export from Mixed Agricultural Watersheds

Land Use	Fertilizer Application kg/ha/yr N P K	Location	Soil Type/Texture	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
58% row crops 31% small grain and pasture 6% woods 5% urban (4950 ha)	44	Black Creek watershed, Harlan, Indiana	silt loam, clay, silty clay loam, silty clay	91.0^{a} (70 - 112)	19.35^{a} (11.2 - 27.5)	28.65^{a} (8.6 - 48.7)	3.15^{a} (1.1 - 5.2)	Lake and Morrison, 1977
63% row crops 26% small grain and pasture 8% woods 3% urban (942 ha)		Smith-Fry drain, Harlan, Indiana	silt loam, clay, silty clay loam, silty clay	91.0^{a} (70 - 112)	20.75^{a} (12.4 - 29.1)	31.76^{a} (10.3 - 53.2)	3.25^{a} (1.1 - 5.4)	Lake and Morrison, 1977
35% row crops 48% small grain and pasture 5% woods 12% urban (714 ha)		Dreisbach Drain, Harlan, Indiana	silt loam, clay, silty clay loam, silty clay	91.0^{a} (70 - 112)	18.05^{a} (10.1 - 26.0)	25.85^{a} (6.6 - 44.1)	3.00^{a} (1.00 - 5.00)	Lake and Morrison, 1977
50% pasture 25% rotation cropland 25% hardwood forest (123 ha)		Coshocton, Ohio	silt loam	88.8^{b} (77.7 - 92.7)	33.35^{b} (26.9 - 34.4)	3.74^{b} (1.67 - 10.61)		Taylor et al., 1971
39% corn 46% legumes and grass 9% small grain 2% idle 4% roads (594 ha)	134 46 120	Ottowa, Ontario, Canada	clay loam, sandy loam	95.1^{c}		18.6^{c} (8.2 - 24.2)	.60^{c} (0.1 - 0.8)	Patni and Hore, 1978
60% row crops 40% hay and pasture 2 livestock feedlots (157.5 ha)	127 28	Macedonia, Iowa	silt loam	67.79	10.74	9.64	.648	Burwell et al., 1974

Table 11: (continued)

Land Use	Fertilizer Application kg/ha/yr N P K	Location	Soil Type/Texture	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
Three years, pasture, two years corn (42.9 ha)	343 67	Treynor, Iowa	silt loam	84.71	17.65	14.11	.27	Burwell, et al., 1977
Intensive Agriculture crops and improved pasture (208 ha)	120 33	North Central, Florida	sand	96.5[a] (88 - 105)	16.7[a] (12.1 - 21.3)	4.23[a] (2.10 - 6.36)	1.1[a] (.86 - 1.34)	Campbell, 1978
Active cropping and pasture		South of Washington, D.C.				2.82	.409	Grizzard et al., 1977
At least 80% of watershed devoted to agricultural activities		Southern Ontario, Canada				14.3[d] (.62 - 23.5)	1.29[d] (.05 - 2.30)	Avadhanula, 1979
37.4% soybean and whitebean 27.1% cereal 23% corn (5080 ha)		Thames River, Southern Ontario, Canada	lacustrine clay over till plain over limestone	72.9		16.1	1.28	Coote et al. (ed.), 1978
36.1% woodland 25.0% cereal 22.2% tobacco 10.1% corn 3% pasture and hay (7913 ha)		Big Creek, Southern Ontario, Canada	deep level deltaic sands			6.4	.26	Coote et al. (ed.), 1978
31.3% corn 26.4% cereal 17.9% pasture and hay 12.1% soybean and whitebean 7.5% woodland (6200 ha)		AuSable River Southern Ontario, Canada	level clay till plain over shale	86.0		41.5	.91	Coote et al. (ed.), 1978

Table 11: (continued)

Land Use	Fertilizer Application kg/ha/yr N P K	Location	Soil Type/Texture	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
37.2% pasture and hay 35.3% cereal 18.7% corn 6.9% woodland (1860 ha)		Grand River, Southern Ontario, Canada	silty clay ground moraine	92.5		20.3	1.00	Coote et al. (ed.), 1978
42.3% corn 22.8% pasture and hay 15.4% woodland 12.2% cereal (3000 ha)		Middle Thames River, Southern Ontario, Canada	calcareous loamy till	101.8		31.1	1.53	Coote et al. (ed.), 1978
33.4% pasture and hay 29.2% woodland 22.3% cereal 12.3% corn		Maitland River, Southern Ontario, Canada	drumlinized loam till	82.3		14.3	.16	Coote et al. (ed.)., 1978
37.4% woodland 28.5% pasture and hay 10.7% cereal 10.4% corn 3.7% tobacco (5645 ha)		Shelter Valley Creek, Southern Ontario, Canada	windblown sand and silt on scoping sandy calcareous till	84.0		3.2	.08	Coote et al. (ed.)., 1978
44.2% pasture and hay 18.4% cereal 17.8% woodland 16.2% corn (3025 ha)		Twenty Mile Creek, Southern Ontario, Canada	lacustrine and reworked clay over dolomite	77.9		15.5	1.53	Coote et al. (ed.), 1978
41.3% pasture and hay 29.0% cereal 11.3% corn 7.5% woodland (2383 ha)		Humber River, Southern Ontario, Canada	stratified clay over shale and limestone	73.7		11.1	.49	Coote et al. (ed.), 1978

Table 11: (continued)

Land Use	Fertilizer Application kg/ha/yr N P K	Location	Soil Type/Texture	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
27.8% vegetables 22.8% corn 10.0% woodland 8.9% cereal 7.9% soybean and whitebean (1990 ha)		Hillman Creek, Southern Ontario, Canada	shallow moraine sand over clay till plain over limestone	77.0		25.2	.91	Coote et al. (ed.), 1978
66.6% pasture and hay 12.1% cereal 9.5% corn 9.4% woodland (4504 ha)		Saugeen River Southern Ontario, Canada	reworked lacustrine clay over clay till	92.4		9.4	.81	Coote et al (ed.), 1978

a. Two year mean
b. Four year median
c. Three year median
d. Estimates based on PLUARG Task C monitoring of selected sites in the Grand and Saugeen River basins.

Table 12: Nutrient Export from Urban Watersheds

Land Use	Location	Soil/Surface Characteristics	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
Residential (50 ha)	Madison, Wisconsin	27% impervious surface	69.93	10.49	5.0	1.1	Kluesener and Lee, 1974
78% industrial 22% commercial (49 ha)	Menominee, Wisconsin	silt and clay loams		24.03[a] (7.88 - 40.18)		2.67[a] (1.06 - 4.28)	Konrad et al., 1978
Commercial (15.8 ha)	Appleton, Wisconsin	clay loam overlying dolomite bedrock	76.5		4.54[b]	.88[b]	Much and Kemp, 1978
Central business district (9.3 ha)	Appleton, Wisconsin	clay loam overlying dolomite bedrock	76.5		38.47[b]	4.08[b]	Much and Kemp, 1978
Industrial (8.1 ha)	Appleton, Wisconsin	clay loam overlying dolomite bedrock	76.5		6.53[b]	.75[b]	Much and Kemp, 1978
Residential (41.7 ha)	Appleton, Wisconsin	clay loam overlying dolomite bedrock	76.5		3.67[b]	.35[b]	Much and Kemp, 1978
Low density residential subdivision, Large lots with complete grass cover and trees (46.82 ha)	Okemos, Michigan	sandy loam, sandy clay loam	77.19		1.52[c]	0.19[c]	Landon, 1977
Low density residential, Extensive grassed areas, small lots, (33.73 ha)	Holt, Michigan	sandy loam, sandy clay loam	77.19		6.9[c]	2.7[c]	Landon, 1977
High density residential townhouse complex, limited open space (7 ha)	East Lansing, Michigan	sandy loam, sandy clay loam	77.19		4.8[c]	1.1[c]	Landon, 1977

Table 12: (continued)

Land Use	Location	Soil/Surface Characteristics	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
High density residential co-operatives, large amounts of open grassed areas (21.63 ha)	Lansing, Michigan	sandy loam, sandy clay loam	77.19		5.5^c	$.56^c$	Landon, 1977
Commercial, Shopping Center (18.19 ha)	Meridian Twp. Ingham Co. Michigan	sandy loam sandy clay loam	77.19		20.5^c	1.7^c	Landon, 1977
Commerical, light industry and business (4.19 ha)	Lansing, Michigan	sandy loam, sandy clay loam	77.19		4.0^c	$.66^c$	Landon, 1977
64% residential 13% recreational 12% commerical 6% transportation 1% industrial (958 ha)	Montgomery Creek, Kitchner Ontario, Canada					.757	O'Neill, 1979
Residential and light commercial (11 ha)	Cincinnati, Ohio	37% impervious surface	76.2	28.19	9.97		Weibel et al., 1964
At least 60% of watershed devoted to urban land use	Southern Ontario, Canada				9.48^d (6.65 - 10.2)	1.63^d (.73 - 2.05)	Avadhanula, 1979
Industrial and residential (414 ha)	Third Creek Watershed, Knoxville, Tennessee	carbonatic bedrock with shales, 28% impervious surfaces	150.0	84.3	14.95	4.17	Betson, 1978
Commercial (212 ha)	Fourth Creek Watershed, Knoxville Tennessee	soluble dolomitic carbonate rock, 45% impervious surfaces	155.0	41.1	12.78	4.85	Betson, 1978

Table 12: (continued)

Land Use	Location	Soil/Surface Characteristics	Precipitation cm/yr	Water Runoff cm/yr	Total Nitrogen Export kg/ha/yr	Total Phosphorus Export kg/ha/yr	Reference
Suburban (62 ha)	Plantation Hills Residential Area Knoxville, Tennessee	soluble dolomitic carbonate rock 23% impervious surfaces	153.0	9.4	1.56	.43	Betson, 1978
60% residential 19% commercial and industrial 12% institutional 10% unused (432.54 ha)	Durham, North Carolina	29% impervious surfaces	108.2	16.26		1.23	Bryan, 1970
60% residential 19% commercial and industrial 12% institutional 10% unused (432.54 ha)	Durham, North Carolina	29% impervious surfaces		24.64		5.26	Colston, 1974
20% urbanized, large scale residential (47900 ha)	Bull Run Basin, Occoquan Watershed, Virginia	sedimentary sandstones and shales			33.76[e]	1.912[e]	Grizzard et al., 1978
Single family residential (19.2 ha)	Broward Co., Florida	quartz sand, 39% impervious surface	125.6	9.42	1.48	0.21	Mattraw and Sherwood, 1977
67% residential 13% commercial 12% woodland 8% agriculture (792 ha)	Tallahasee, Florida	well drained loamy soils	249.0	48.3		6.23	Burton et al., 1977
Residential (6.8 ha)	Durban, South Africa	quartz sand with some clay content, 20% impervious surface	113.06	18.99	4.0	0.6	Simpson and Hemens, 1978

a. two year mean
b. Estimates based on annual streamflow measurements and nine monitored runoff events during 8 month water quality sampling period
c. Estimates based on annual streamflow measurements and five months water quality sampling
d. Estimates based on PLUARG Task C monitoring of selected sites in the Saugeen and Grand River basins
e. Suspected of having nonurban influences

TABLE 13a: Forest Atmospheric Inputs

LOCATION	PHOSPHORUS (kg/ha/yr) Dissolved-P	Total-P	NITROGEN (kg/ha/yr) NO_3-N	NH_3-N	Organic-N	Total-N	REFERENCE
Rawson Lake, Ontario, Canada		.327				6.27	Schindler et al., 1976
Clear Lake, Ontario, Canada		.26	——7.153——				Schindler et al., 1970
White Mountains, New Hampshire			6.0	2.8			Martin, 1979
Hubbard Brook Exp. Forest New Hampshire	.035		4.3	2.24			Likens et al., 1977
Walker Branch Watershed Tennessee		.54	3.9	2.0		8.7	Henderson, 1977
Coweeta Experimental Watershed, N. Carolina		.19	2.88	.52			Swank & Henderson, 1976
North Carolina		.21	——5.54——				Wells & Jorgensen, 1975
Duke Forest, N. Carolina		.28	1.46	.74	1.33	3.53	Wells et al., 1972
N. East, Minnesota		.14					Wright, 1976
H.J. Andrews Exp. Forest, Western, Oregon		.27	.135	.85		.99	Fredriksen, 1972
N. Central, Minnesota		.48	2.25	2.74	2.32	7.32	Verry & Timmons, 1977
Mississippi		.3				11.3	Switzer & Nelson, 1972
Northern Mississippi		.07	3.12	5.73			Schreiber et al., 1976
Northern Mississippi		.41					Duffy et al, 1978
New Mexico			2.64	1.74	2.39	6.77	Gosz, 1978
Sapelo Is., Georgia			1.255	.95	.633	2.84*	Haines et al., 1976
Watersmeet, Michigan		.19					Eisenreich et al., 1977
Beaver Island, Mich.	.036	.216					Eisenreich et al., 1977
Beaver Island, Mich.	.032						Murphy & Doskey, 1976
Rock Island St. Pk., Wis.	.039						Murphy & Doskey, 1976
Finger Lakes Area, NY		.181	5.37	3.37			Likens, 1972

*wetfall only

TABLE 13b: Agricultural-Rural Atmospheric Inputs

LOCATION	PHOSPHORUS (kg/ha/yr)		NITROGEN (kg/ha/yr)				REFERENCE
	Dissolved-P	Total-P	NO_3-N	NH_3-N	Organic-N	Total-N	
Treynor, Iowa			——7.26——				Schuman & Burwell, 1974
Rhode River Watershed Edgewater, Maryland		.82	4.71		5.66	10.49	Miklas et al., 1977
Coshocton, Ohio		.20	——8.8——				Chichester et al., 1979
Morris, Minnesota		.125	2.45	5.09			Burwell et al., 1975
Southern Ontario, Canada		.97				38.0	Sanderson, 1977
Pellston, Michigan	.20	.25	4.85	3.09			Richardson & Merva, 1976
Houghton Lake, Michigan	.29	.31	3.21	2.09			Richardson & Merva, 1976
Silver Lake St. Pk., Michigan	.086						Murphy et al., 1976
Wisconsin			3.51	12.22	14.43	30.16	Hoeft et al., 1972
Wisconsin			2.73	2.86	6.54	13.13	Hoeft et al., 1972
Great Britain		.74				13.1	Frissel 1978
Eatonton, Georgia		.192					Krebs & Golley, 1977

TABLE 13c: Urban-Industrial Atmospheric Inputs

LOCATION	PHOSPHORUS (kg/ha/yr)		NITROGEN (kg/ha/yr)				REFERENCE
	Dissolved-P	Total-P	NO_3-N	NH_3-N	Organic-N	Total-N	
Washington, D.C.		2.58**				9.09**	Randall et al., 1978
Knoxville, Tennessee	2.17	3.67	4.4	3.4	24.8	24.8	Betson et al., 1978
San Francisco, Cal.		.26	.23	.76			McDoll et al., 1978
Wisconsin			3.73	3.61	6.19	13.53	Hoeft et al., 1972
Madison, Wisconsin		.99				24.0	Likens & Loucks, 1978
Madison, Wisconsin		1.02				23.0	Kluesener, 1972
Milwaukee, Wisc.		.372					Eisenreich et al., 1977
Grand Haven, Mich		.415					Eisenreich et al., 1977
Saginaw Bay, Mich	1.12	1.21	4.73				Richardson et al., 1976
Chicago, Illinois	.327						Murphy et al., 1976
Chicago, Illinois	.084	.558					Eisenreich et al., 1977
Halifax, Nova Scotia		.56	1.21				Hart & Ogden, 1977
Durban, South Africa	.27	.52	3.95	4.22	14.74	22.91	Simpson & Hemens, 1979
Munich, Germany		.80	8.26	3.6			Goettle, 1978
Hamburg, Germany		2.0	3.3	20.2		23.5	Frissel, 1978
Stockholm, Sweden		1.6	.8	2.1		7.4	Frissel, 1978
London, England		2.1	2.5	17.3		19.8	Frissel, 1978
Paris, France		1.6	2.3	14.8		17.1	Frissel, 1978

**dustfall only

Table 14: Nutrient Loads for Household Wastewater Discharged into Septic Tanks. (kg/capita/yr).

Total P	Total N	Reference
1.49	6.45	Ligman et al, 1974
1.43	5.99	Laak, 1975
	2.65	Bennet and Linstedt, 1975
.74	4.61	Chan et al, 1978
1.59		Ellis and Childs, 1973
1.49	2.15	Siegrist et al, 1976
3.00		Bernhard, 1975
.80		Otis et al, 1975
	8.20	Walker et al, 1973
1.28	3.20	EPA-NES, 1974

Table 15: Magnitude and Variability for Phosphorus Loading from Waste Water Treatment Plant Effluent*

Treatment Type	Median Loading (kg/capita/yr)	Range (kg/capita/yr)	Sample Size
Activated Sludge	.89	.32 - 4.99	183
Trickling Filter	1.10	.39 - 5.44	158
Phosphorus Removal	.57	.23 - 1.81	16
Primary Settling and Digestion	.82	.27 - 3.18	53
Oxidation Pond	1.07	.36 - 3.63	52
Sand Filter	2.86	.77 - 6.11	11

*Ten to fourteen samples taken per year. Adapted from EPA-NES Working Paper Number 22 (U.S.E.P.A., 1974)

Figure 4a: PHOSPHORUS EXPORT FROM FORESTED WATERSHEDS

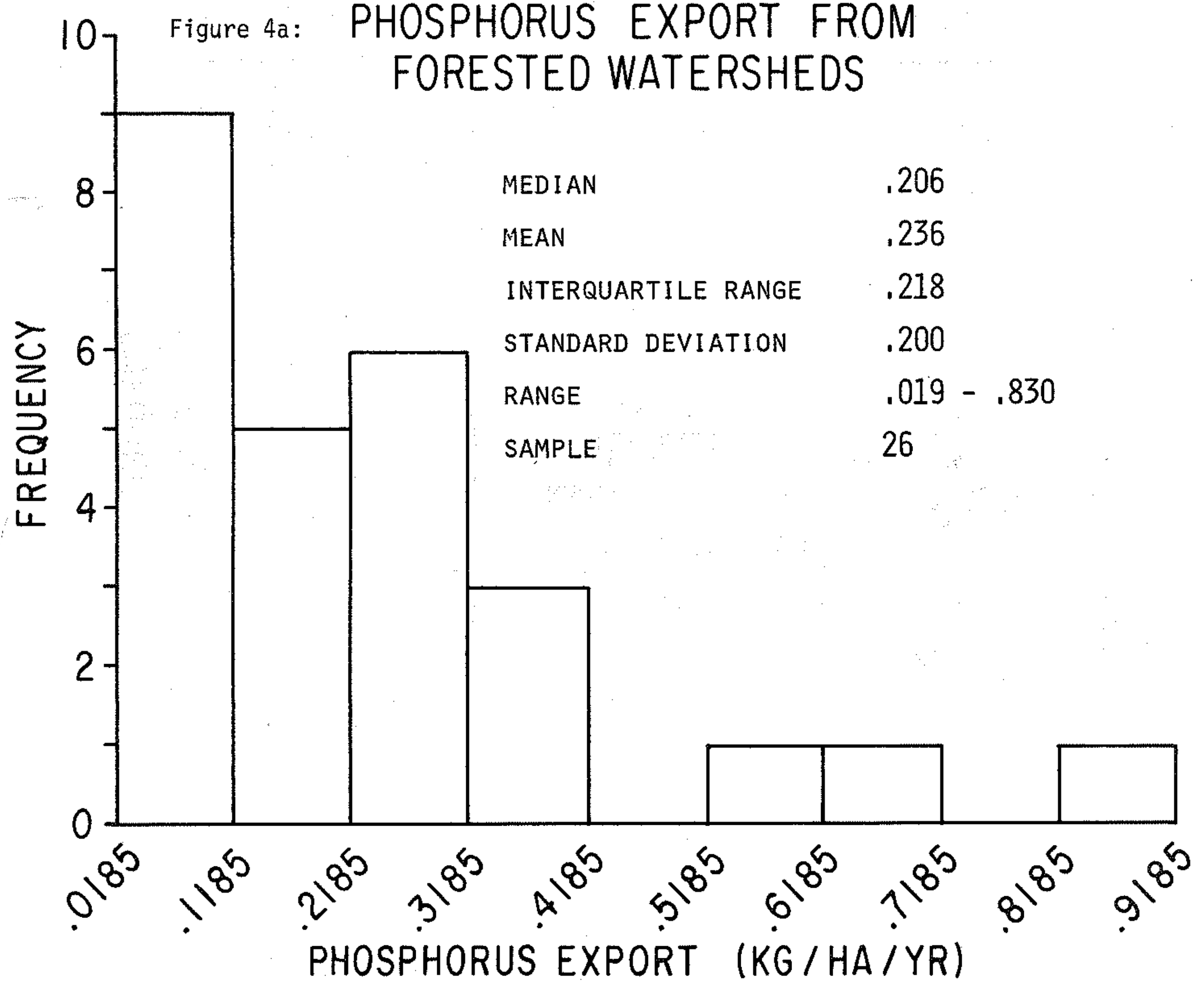
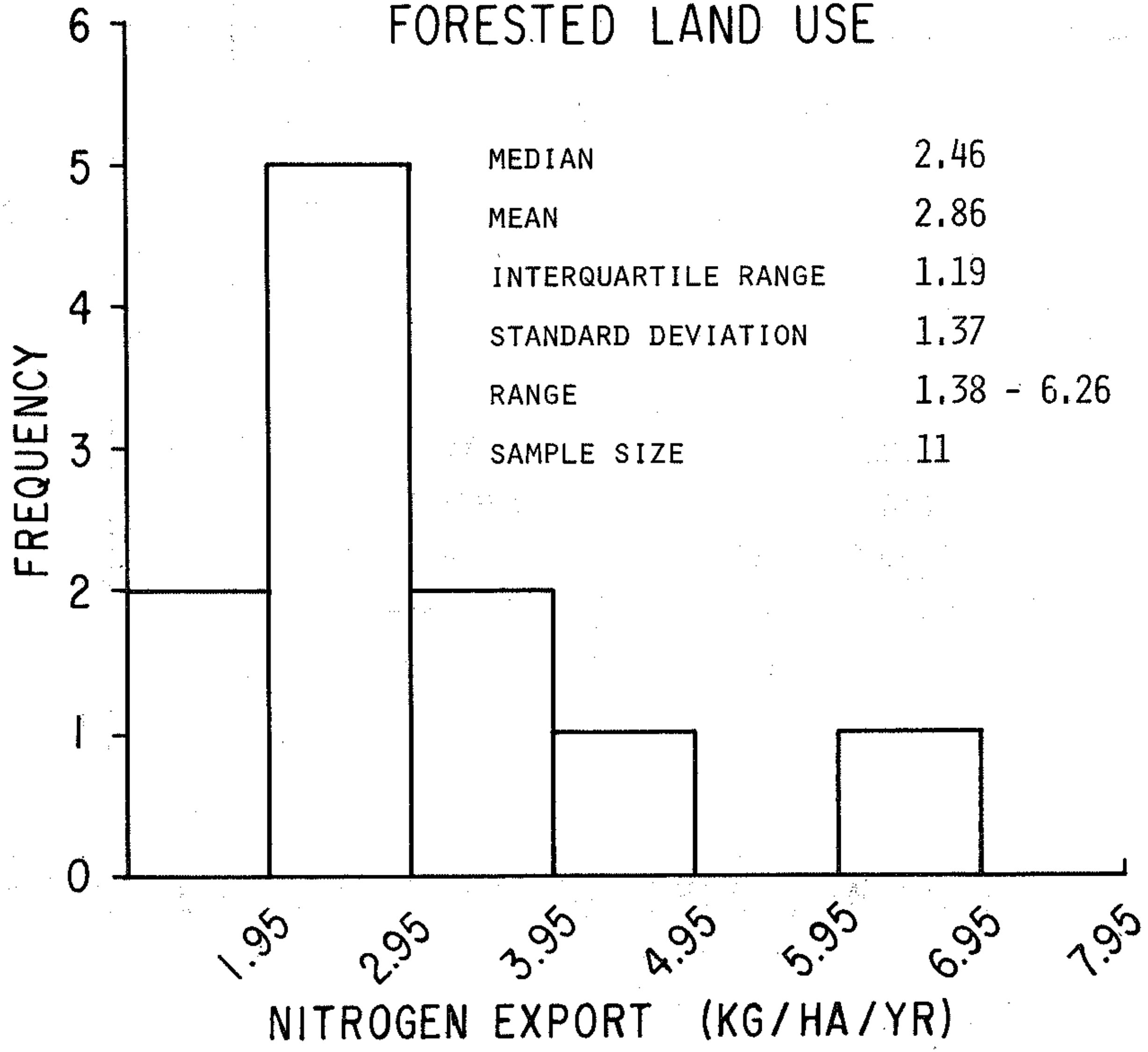


Figure 4b: NITROGEN EXPORT FROM FORESTED LAND USE



MEDIAN	2.46
MEAN	2.86
INTERQUARTILE RANGE	1.19
STANDARD DEVIATION	1.37
RANGE	1.38 - 6.26
SAMPLE SIZE	11

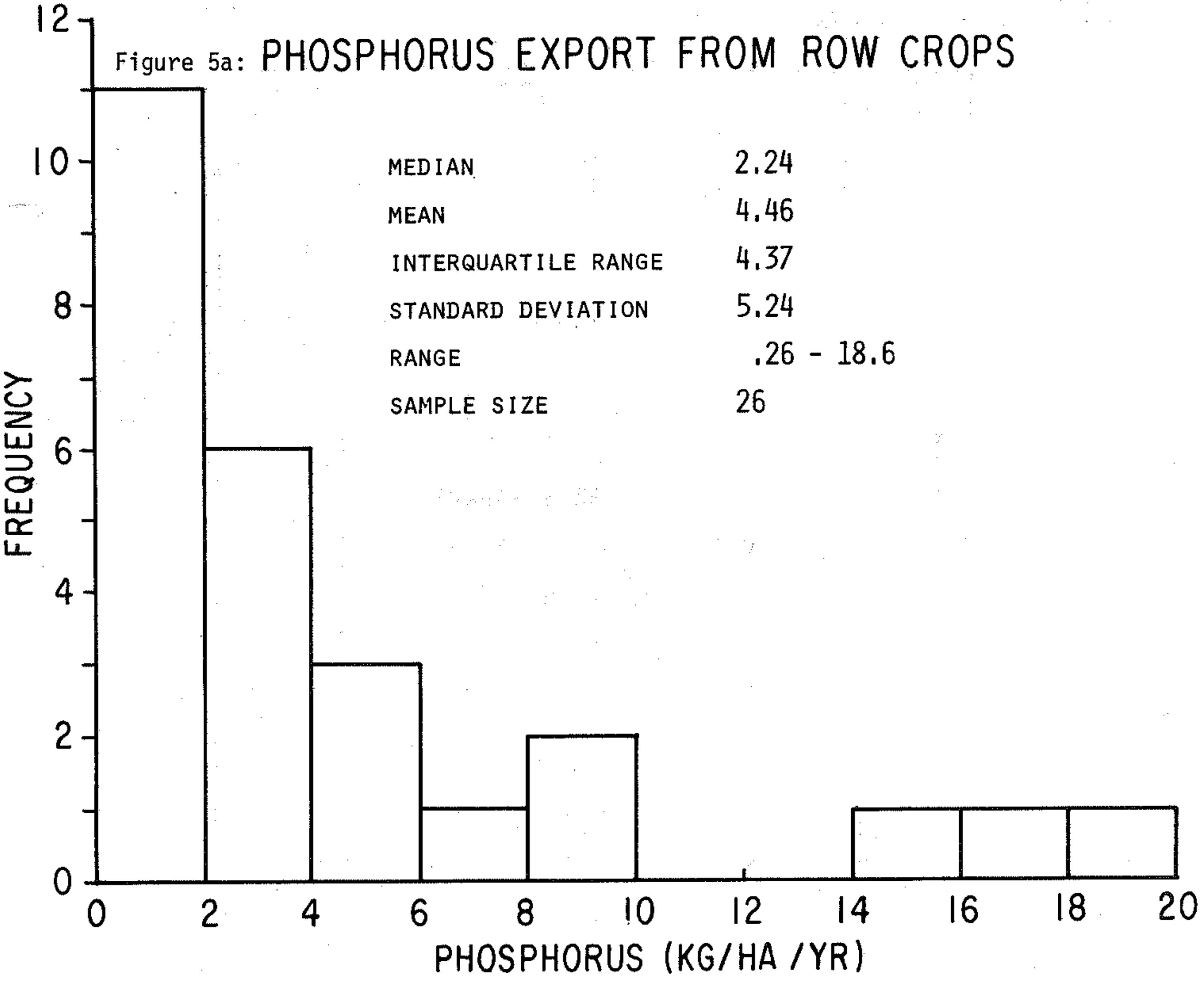
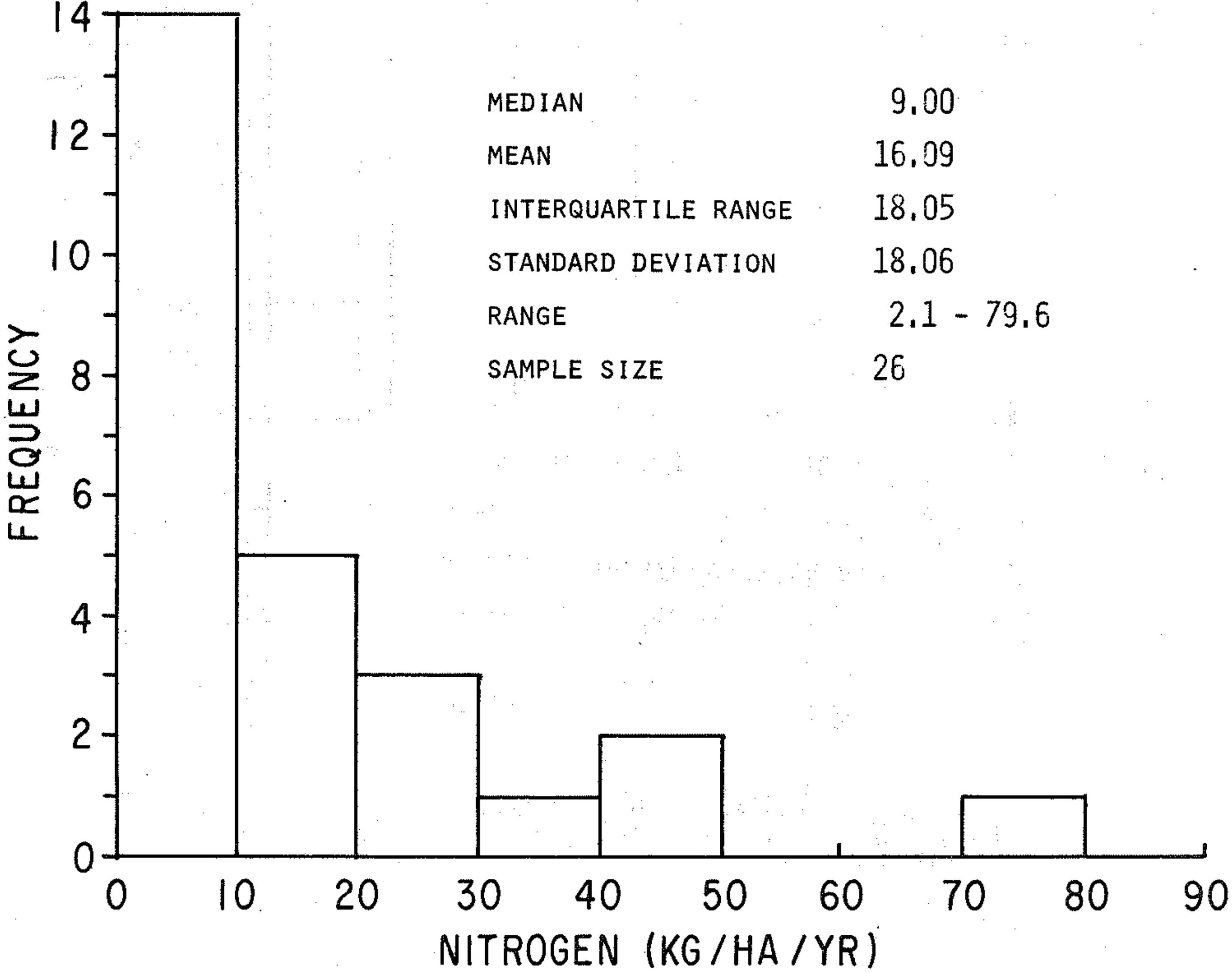


Figure 5a: PHOSPHORUS EXPORT FROM ROW CROPS

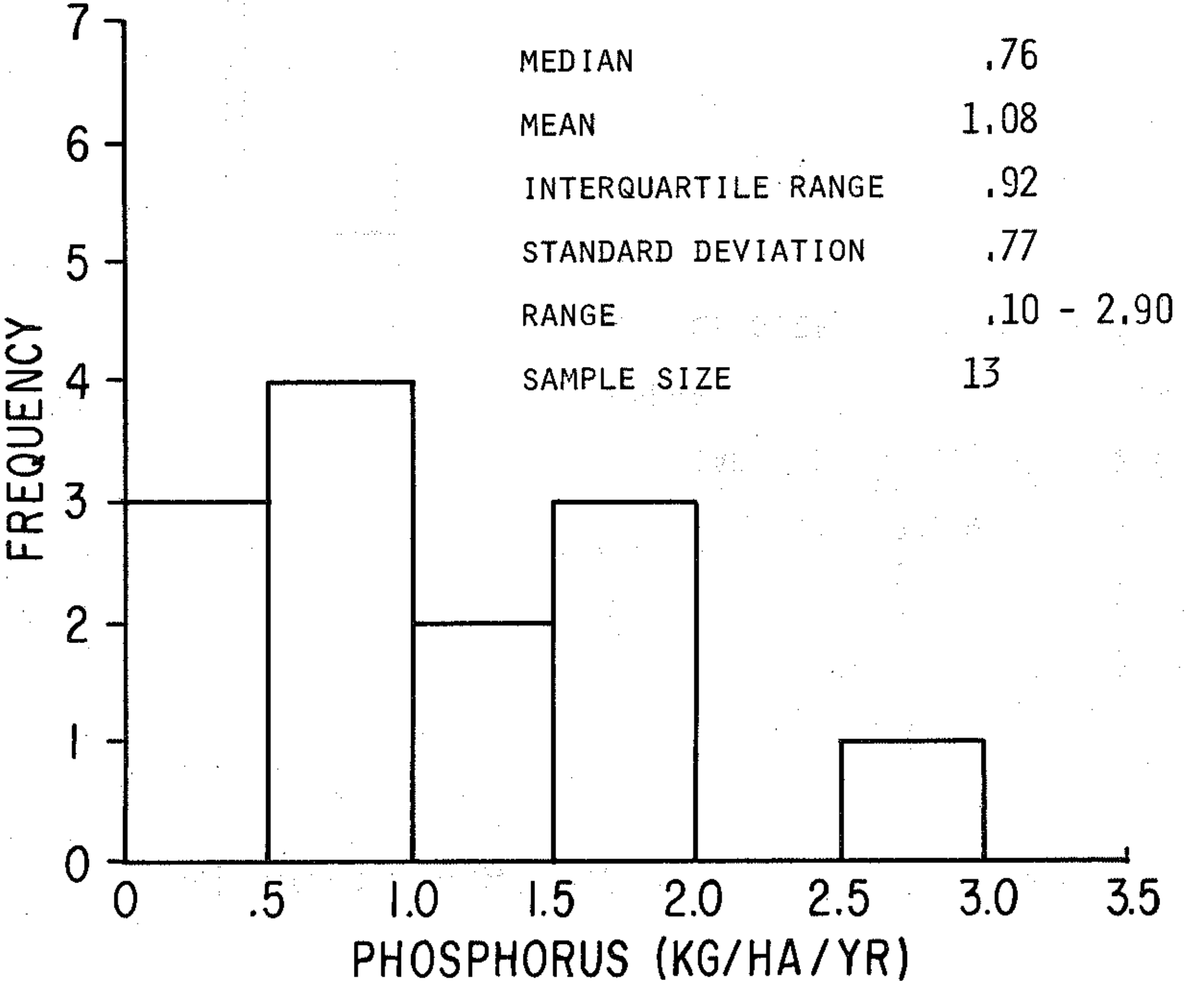
MEDIAN	2.24
MEAN	4.46
INTERQUARTILE RANGE	4.37
STANDARD DEVIATION	5.24
RANGE	.26 - 18.6
SAMPLE SIZE	26

Figure 5b: NITROGEN EXPORT FROM ROW CROPS



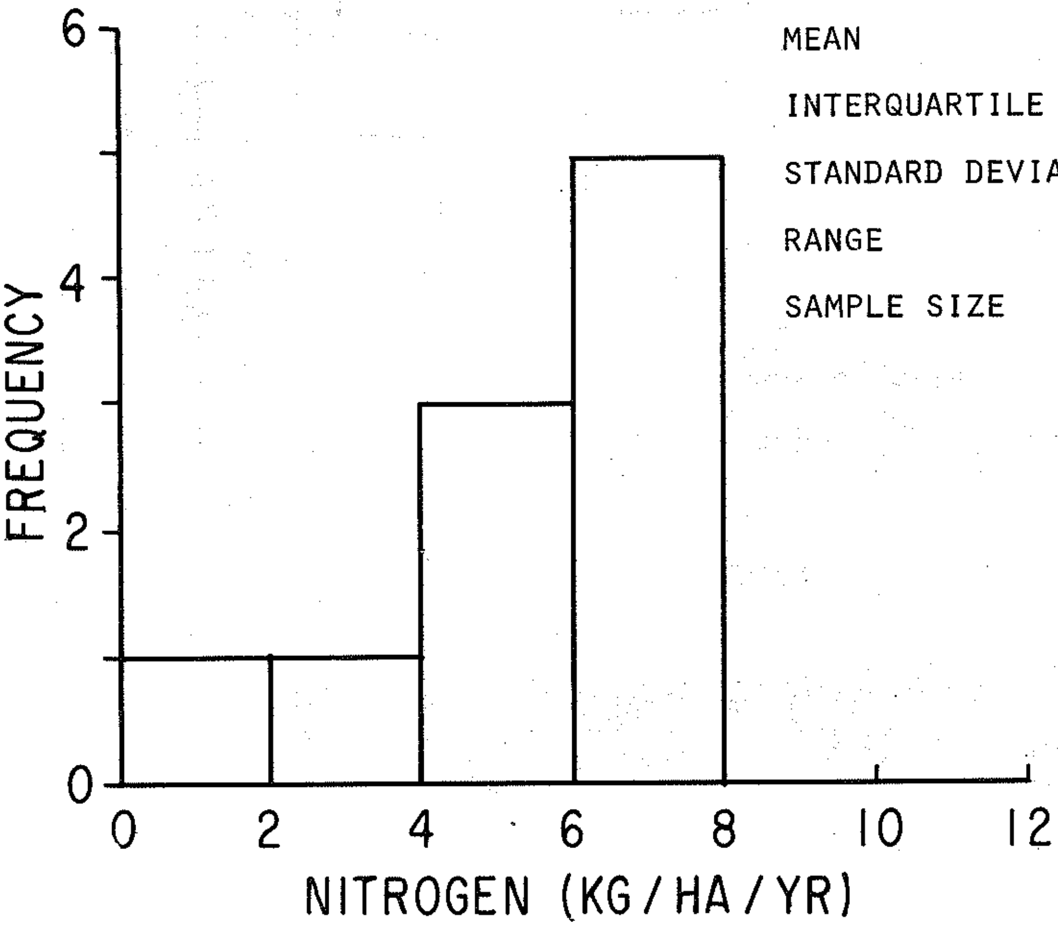
MEDIAN	9.00
MEAN	16.09
INTERQUARTILE RANGE	18.05
STANDARD DEVIATION	18.06
RANGE	2.1 - 79.6
SAMPLE SIZE	26

Figure 6a: PHOSPHORUS EXPORT FROM NONROW CROPS



MEDIAN	.76
MEAN	1.08
INTERQUARTILE RANGE	.92
STANDARD DEVIATION	.77
RANGE	.10 - 2.90
SAMPLE SIZE	13

Figure 6b: NITROGEN EXPORT FROM NONROW CROPS



MEDIAN	6.08
MEAN	5.19
INTERQUARTILE RANGE	2.38
STANDARD DEVIATION	2.07
RANGE	.97 - 7.82
SAMPLE SIZE	10

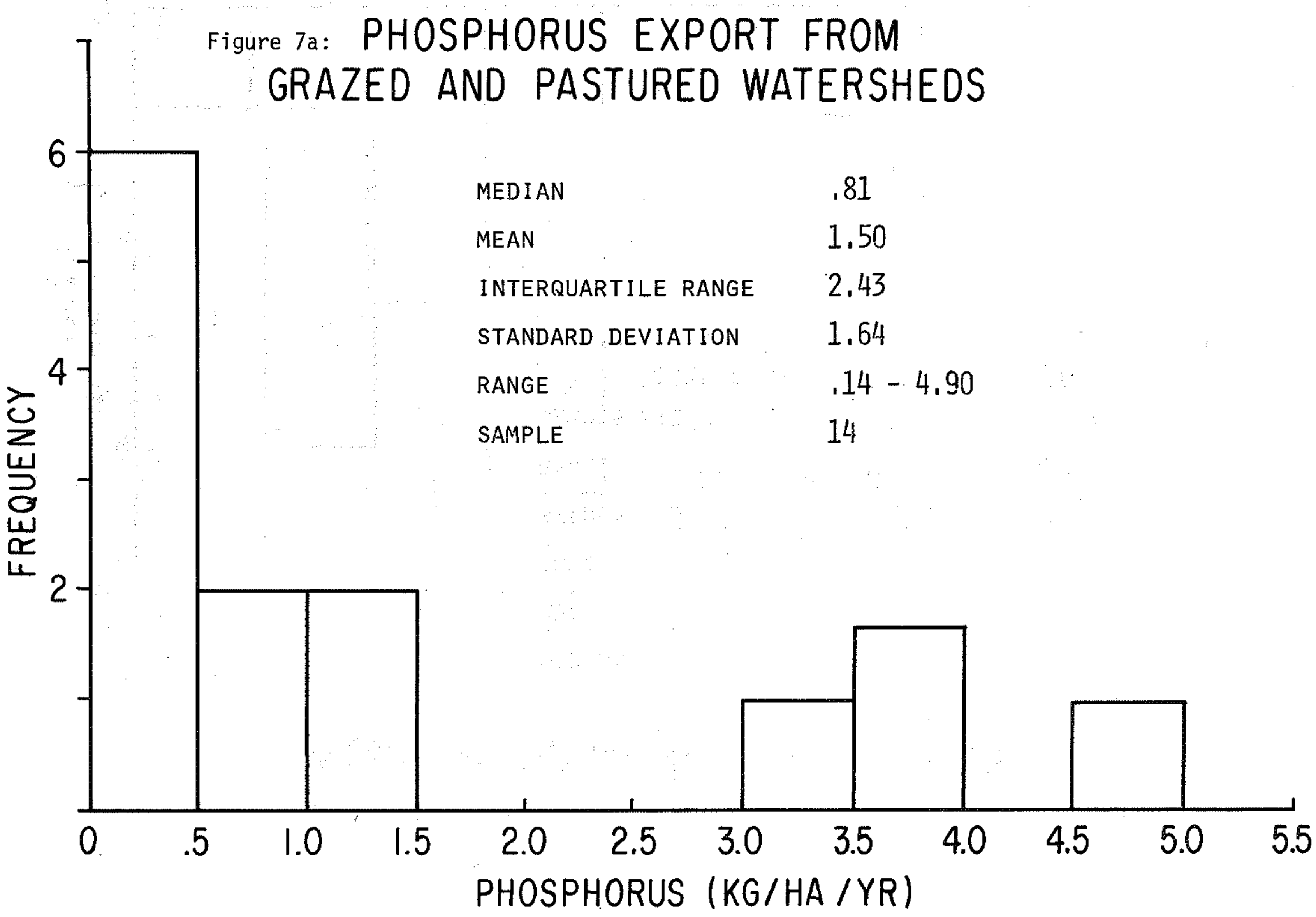
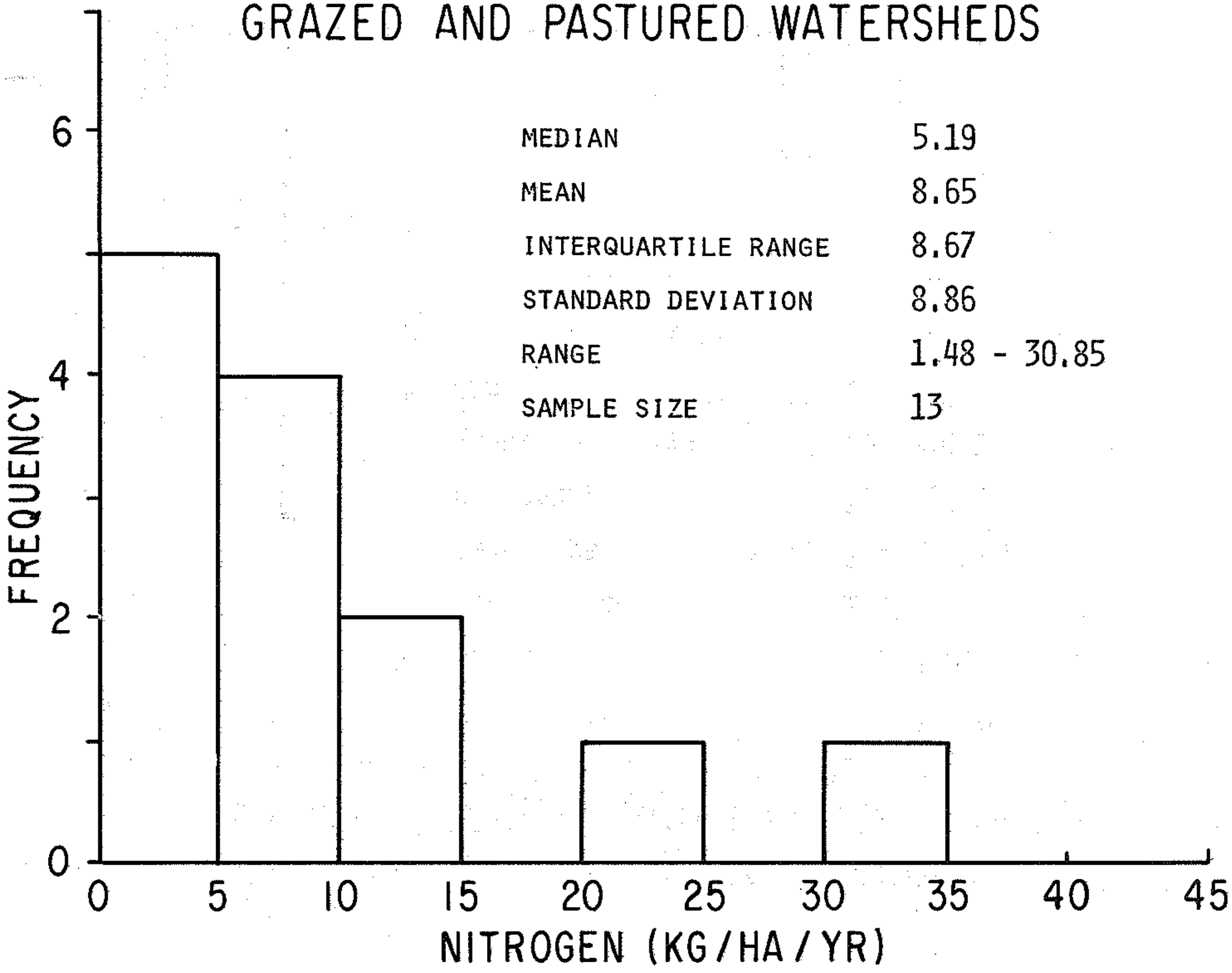


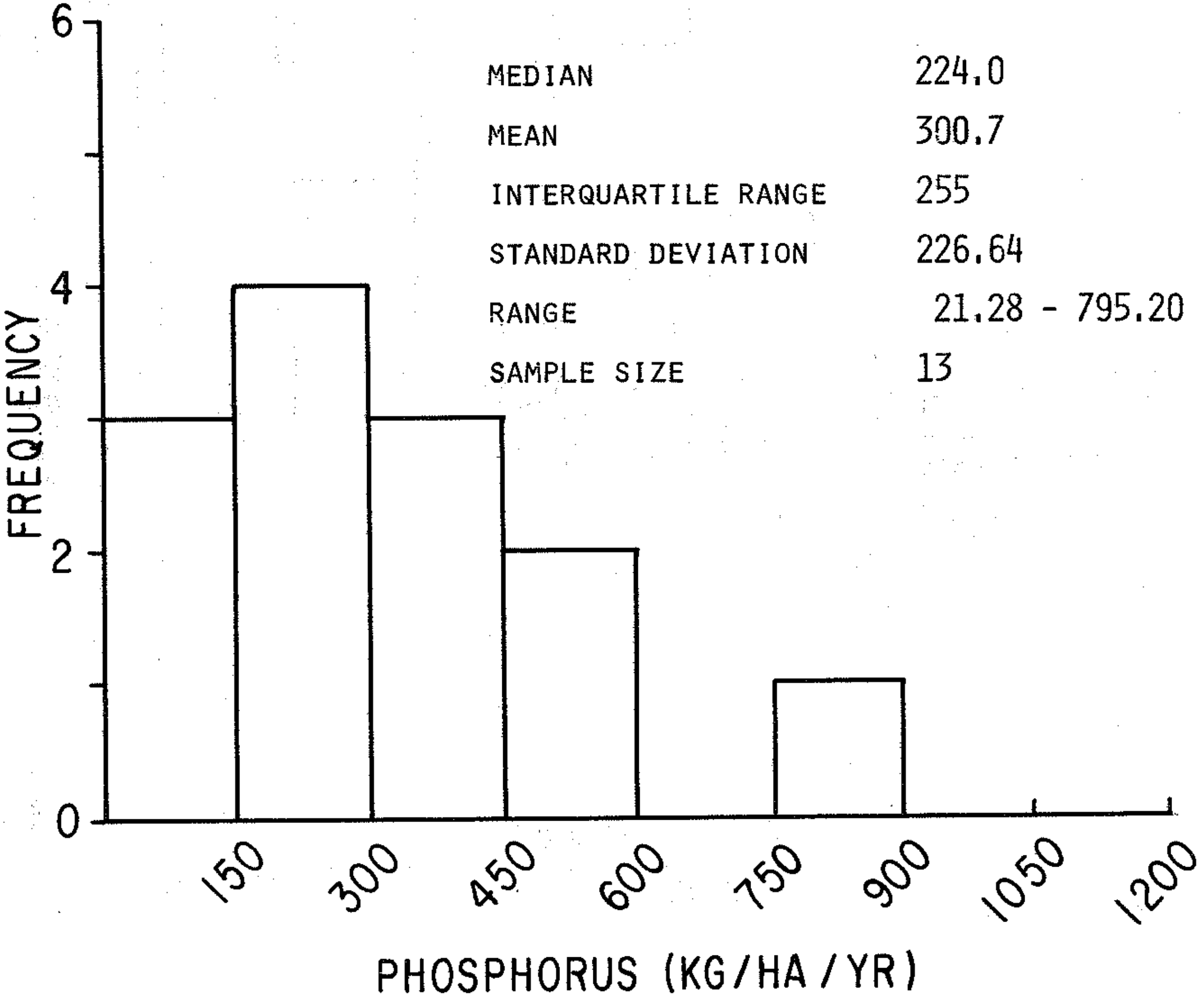
Figure 7a: PHOSPHORUS EXPORT FROM GRAZED AND PASTURED WATERSHEDS

Figure 7b: NITROGEN EXPORT FROM GRAZED AND PASTURED WATERSHEDS



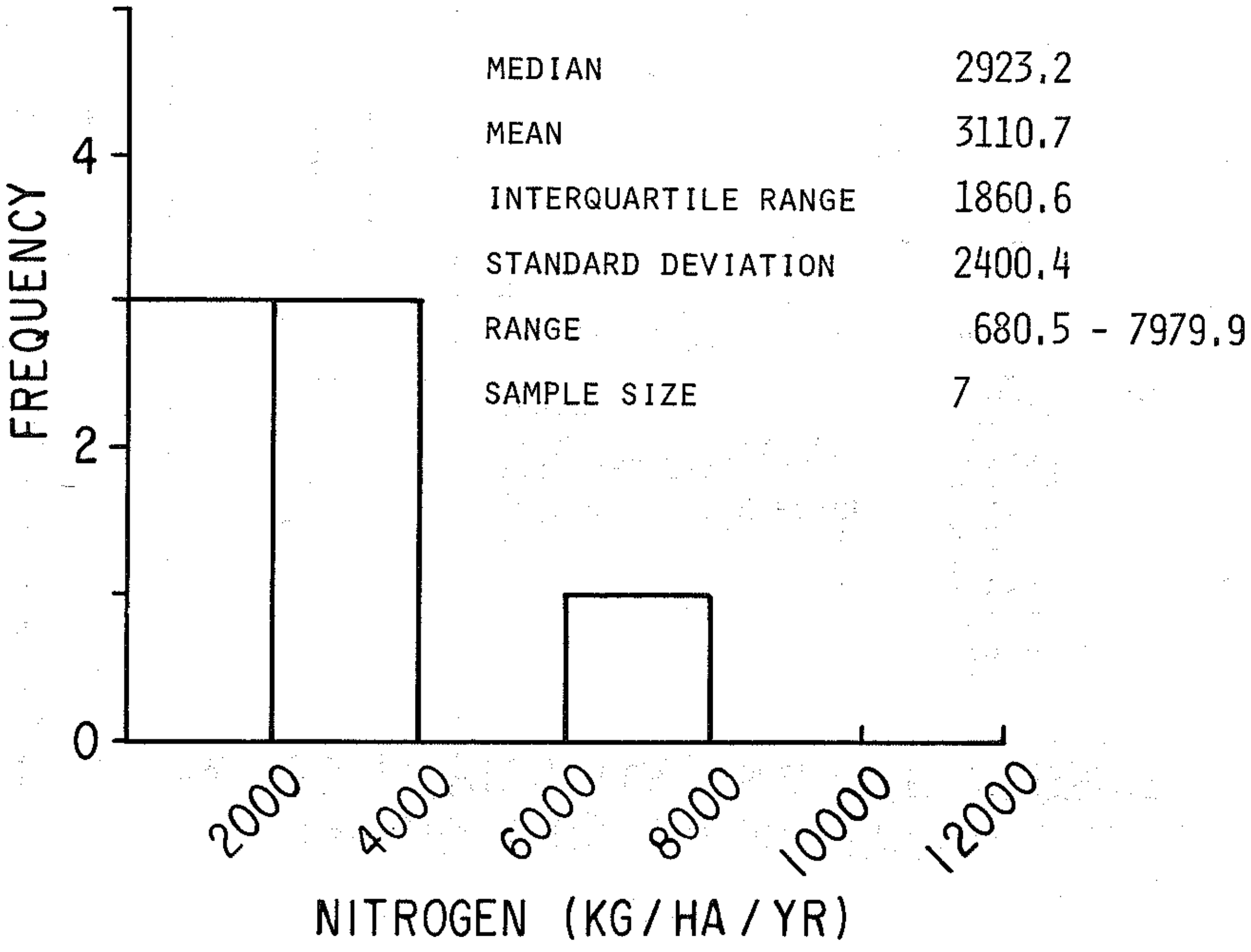
MEDIAN	5.19
MEAN	8.65
INTERQUARTILE RANGE	8.67
STANDARD DEVIATION	8.86
RANGE	1.48 - 30.85
SAMPLE SIZE	13

Figure 8a: PHOSPHORUS EXPORT FROM ANIMAL FEEDLOT AND MANURE STORAGE



MEDIAN	224.0
MEAN	300.7
INTERQUARTILE RANGE	255
STANDARD DEVIATION	226.64
RANGE	21.28 - 795.20
SAMPLE SIZE	13

Figure 8b: NITROGEN EXPORT FROM ANIMAL FEEDLOT AND MANURE STORAGE



MEDIAN	2923.2
MEAN	3110.7
INTERQUARTILE RANGE	1860.6
STANDARD DEVIATION	2400.4
RANGE	680.5 - 7979.9
SAMPLE SIZE	7

Figure 9a: PHOSPHORUS EXPORT FROM MIXED AGRICULTURAL WATERSHEDS

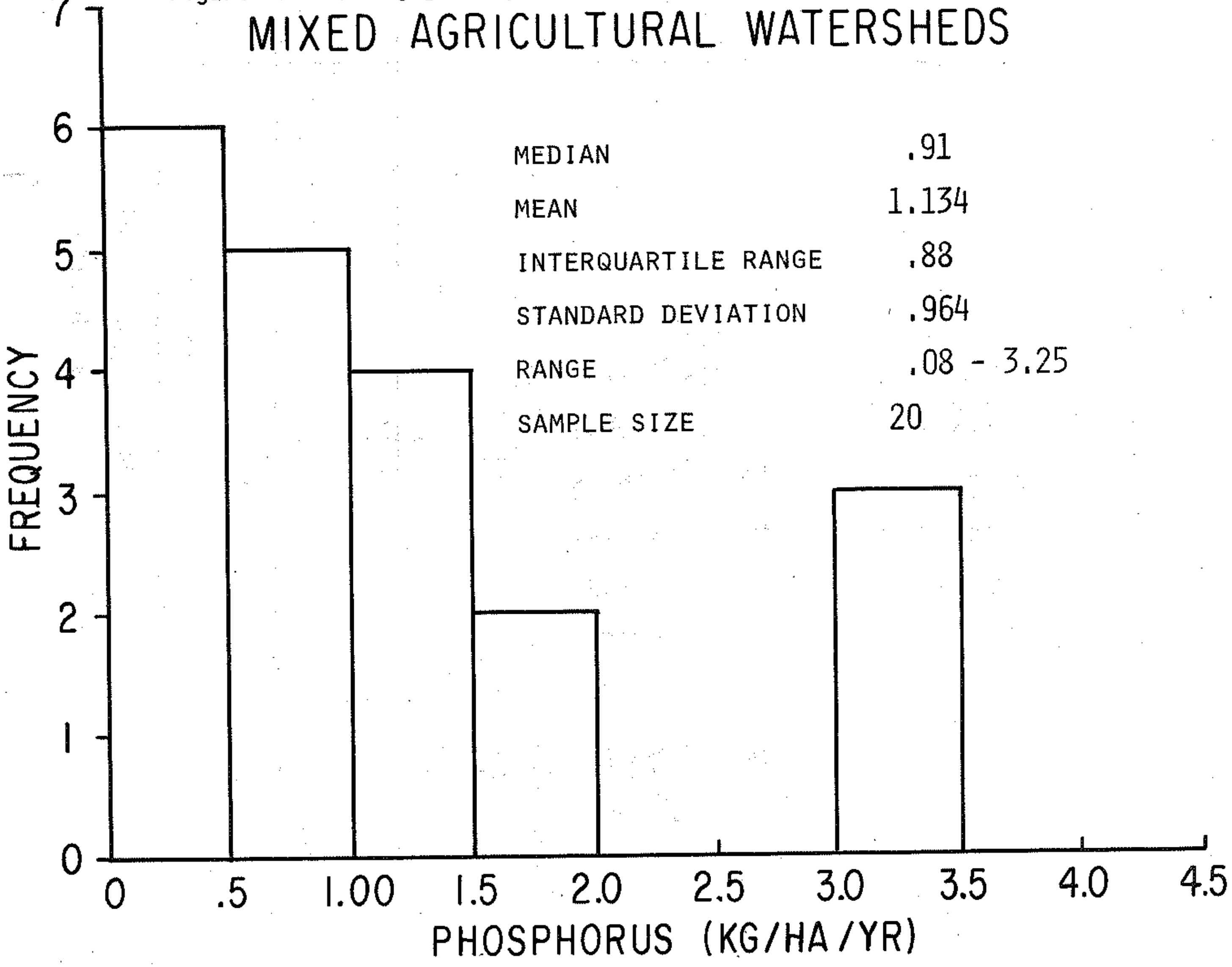
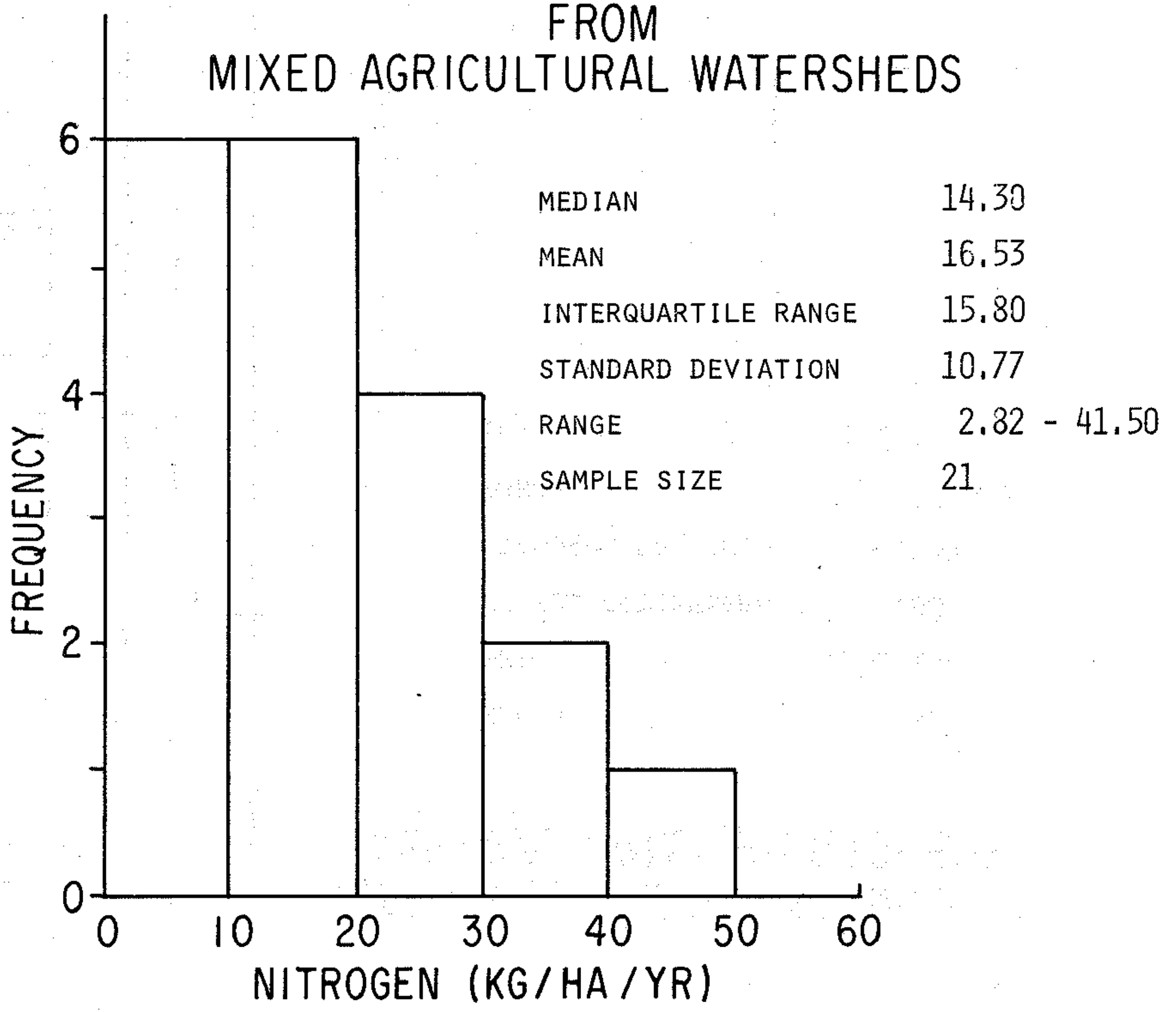
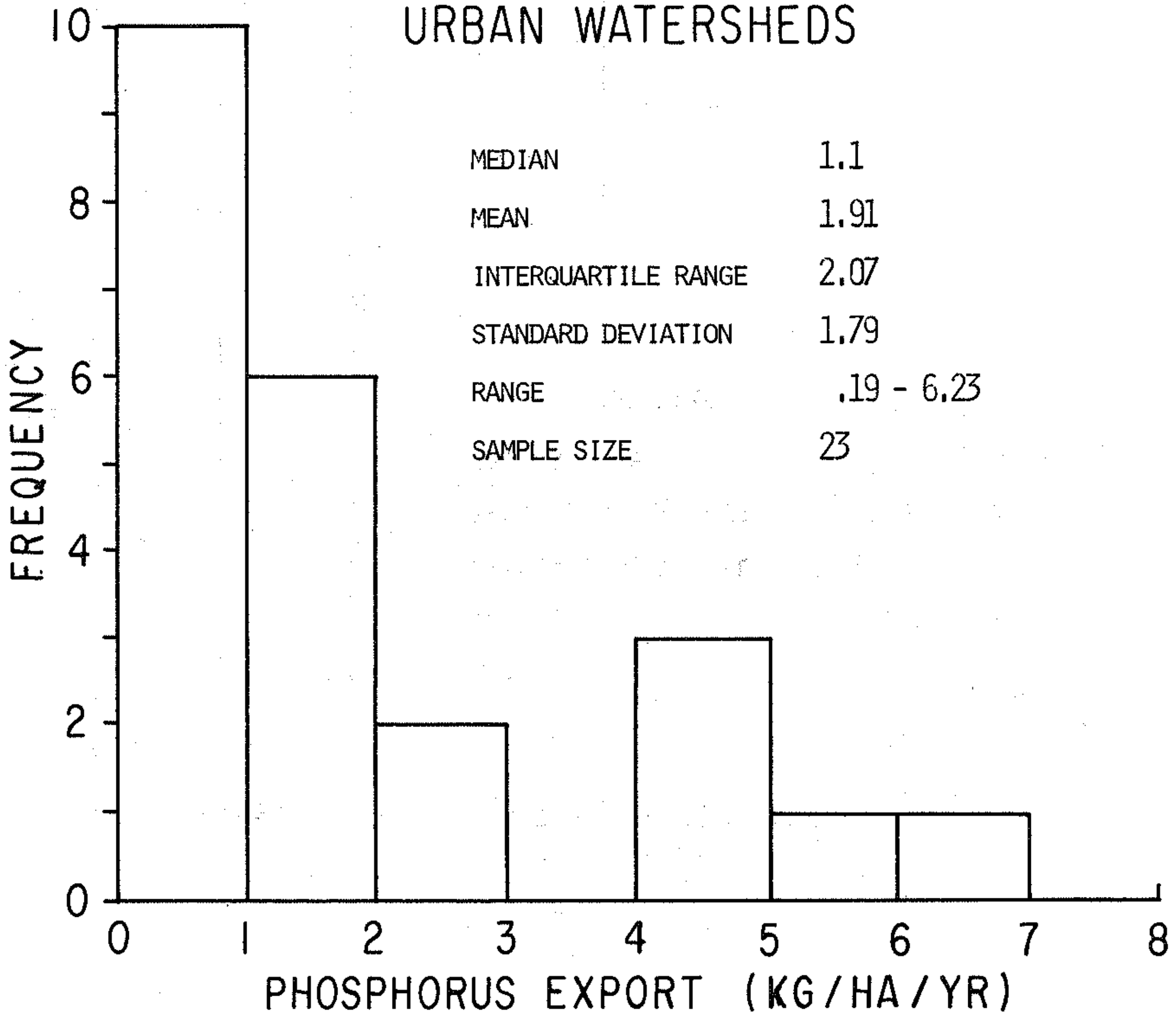


Figure 9b: NITROGEN EXPORT FROM MIXED AGRICULTURAL WATERSHEDS



MEDIAN	14.30
MEAN	16.53
INTERQUARTILE RANGE	15.80
STANDARD DEVIATION	10.77
RANGE	2.82 - 41.50
SAMPLE SIZE	21

Figure 10a: PHOSPHORUS EXPORT FROM URBAN WATERSHEDS



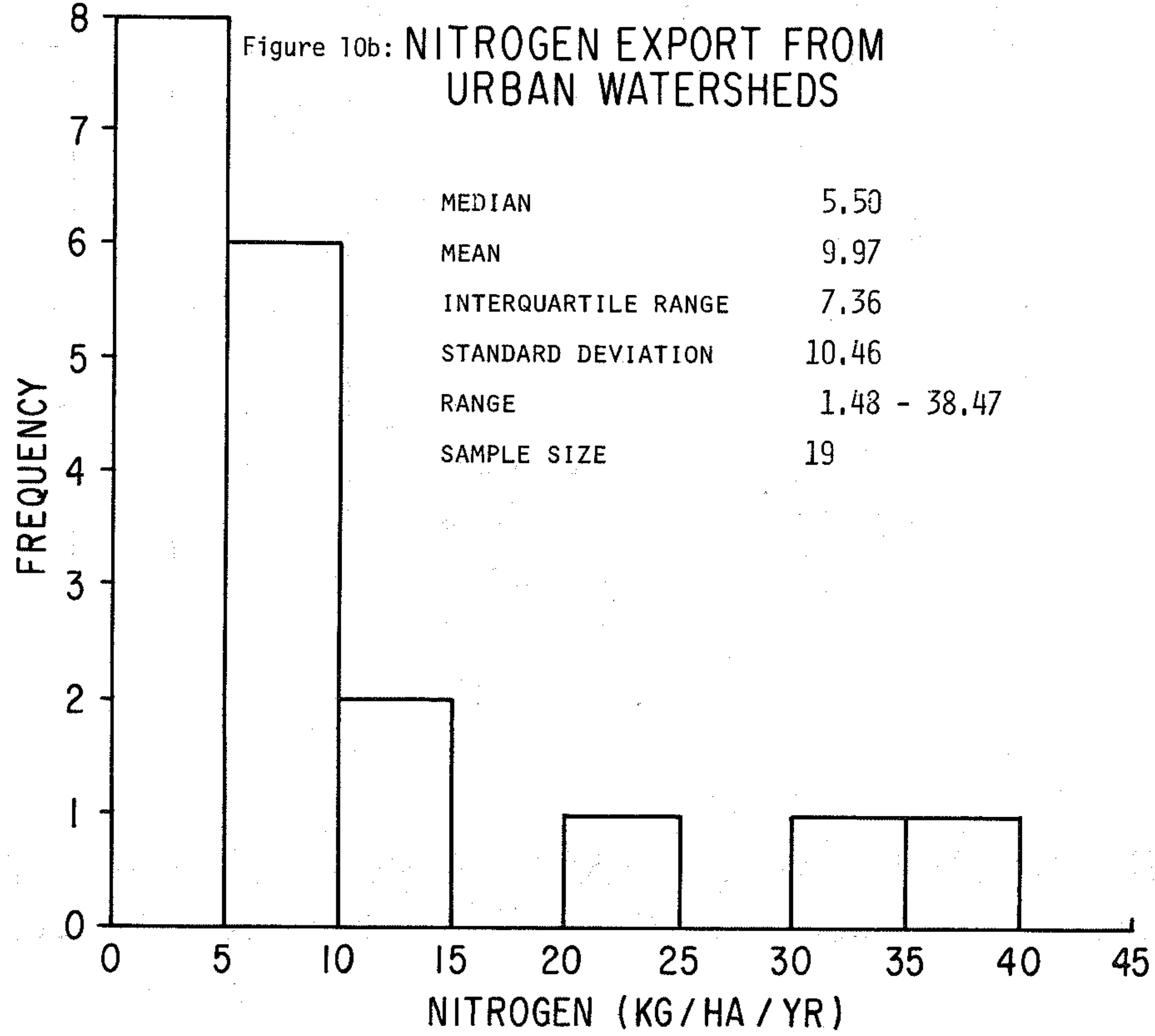
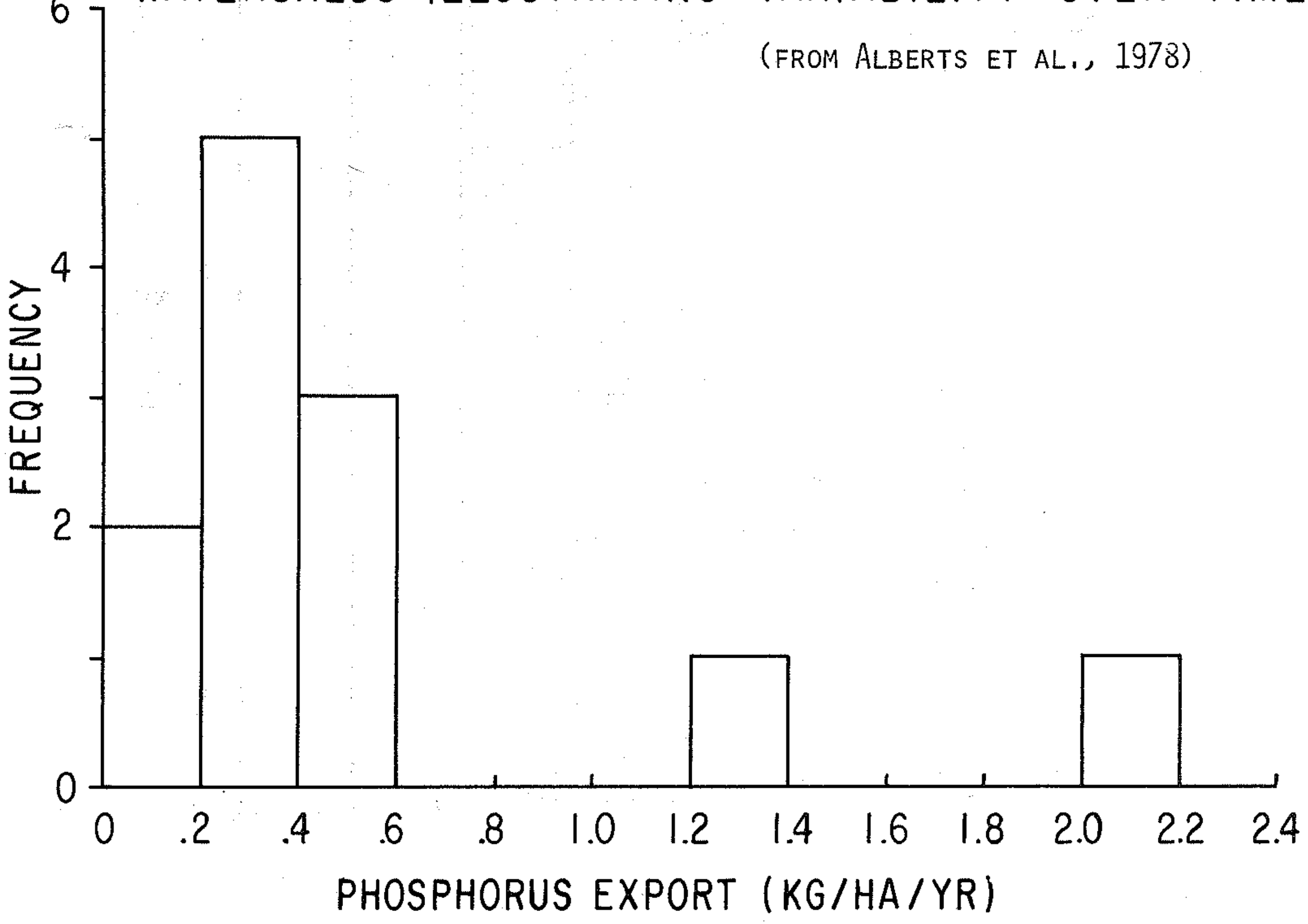


Figure 10b: NITROGEN EXPORT FROM URBAN WATERSHEDS

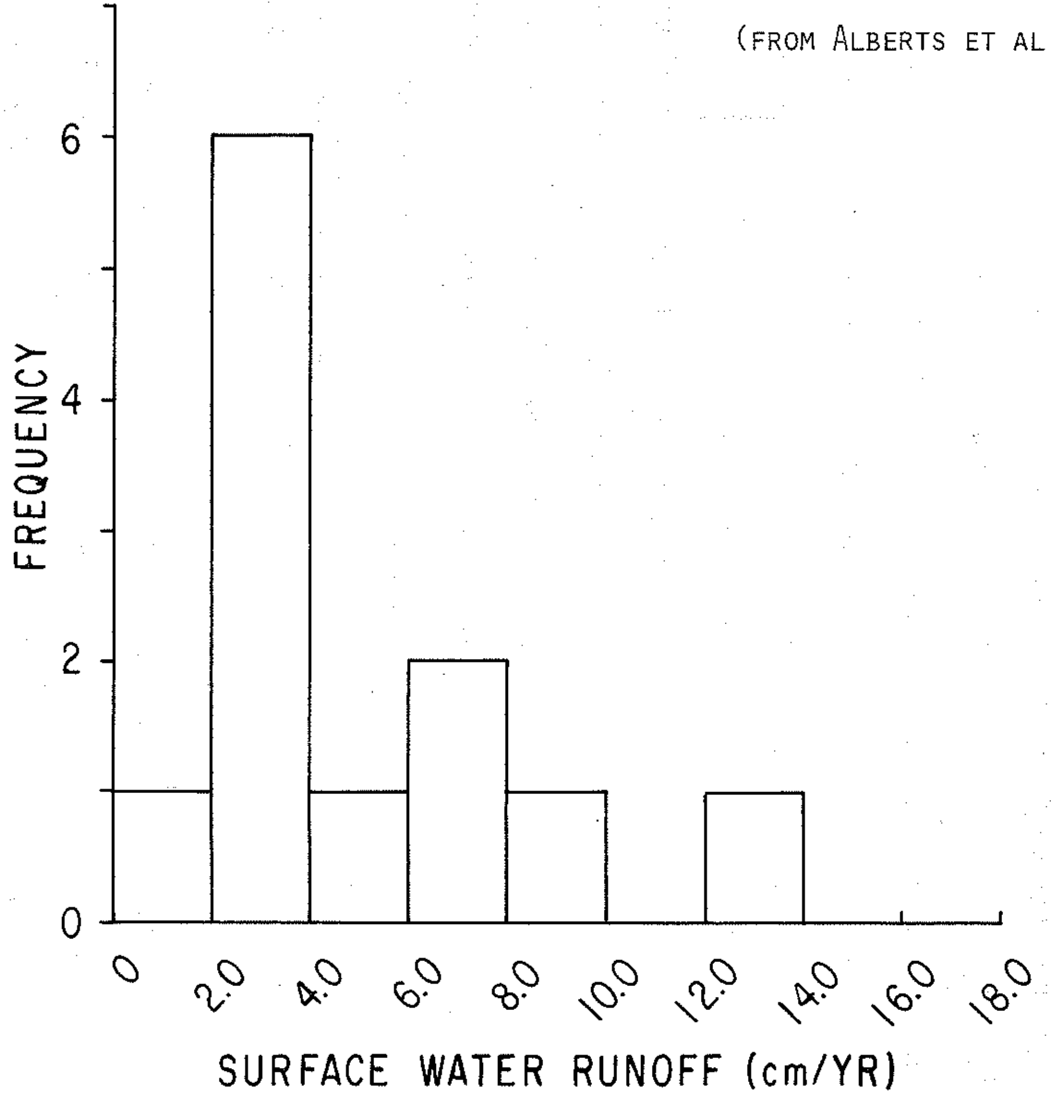
MEDIAN	5.50
MEAN	9.97
INTERQUARTILE RANGE	7.36
STANDARD DEVIATION	10.46
RANGE	1.48 - 38.47
SAMPLE SIZE	19

Figure 11: TOTAL PHOSPHORUS EXPORT FROM TWO CORN CROPPED WATERSHEDS ILLUSTRATING VARIABILITY OVER TIME



(FROM ALBERTS ET AL., 1978)

Figure 12: SURFACE WATER RUNOFF FROM TWO CORN CROPPED WATERSHEDS ILLUSTRATING VARIABILITY OVER TIME



(FROM ALBERTS ET AL., 1978