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THE ADVISORY SYSTEM FOR FERTILIZER APPLICATION IN THE GERMAN DEMOCRATIC REPUBLIC EMPHASIZING THE MINIMIZATION OF NITROGEN POLLUTION

K. Beer
H. Ansorge
H. Görlitz

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

PREFACE

This paper describes one of three operational state computer systems used to give advice on agricultural problems in the GDR. The system, employed nationwide, is oriented to providing advice about fertilizer application on farms or even single fields. Of the other two computer systems, one is described in IIASA CP-79-18, "Environmental Problems of Agriculture II: Pest and Weed Management: Monitoring and Forecasting in the German Democratic Republic." The remaining operational system is applied to irrigation.

At IIASA's request, the present paper emphasizes the methods of the system for determining the optimal amount of fertilizer to apply which allows for maximum agricultural production without wasting resources or harming the environment. The paper thus offers another contribution to the solution of nonpoint source chemical pollution problems which have been intensively studied at IIASA both in-house and in cooperation with other institutions.

Genady N. Golubev
Task Leader
Environmental Problems of Agriculture

THE ADVISORY SYSTEM FOR FERTILIZER APPLICATION IN THE GERMAN DEMOCRATIC REPUBLIC EMPHASIZING THE MINIMIZATION OF NITROGEN POLLUTION

By K. BEER, H. ANSORGE, H. GÖRLITZ

Institut für Düngungsforschung Leipzig-Potsdam der Akademie der Landwirtschaftswissenschaften der Deutschen Demokratischen Republik
(Institute of Fertilization Research Leipzig-Potsdam of the Academy of Agricultural Sciences of the German Democratic Republic)

1. Introduction

Agriculture in the German Democratic Republic (GDR) faces the task to continuously supply high-quality food to the population and raw materials to the manufacturing industry. To fulfill this task, agricultural production has to be further intensified. Among the intensification factors, extensive chemicalization is of great importance. For this reason, special attention has to be given to the effective use of the available amounts of nitrogen fertilizers.

Whereas the share of nitrogen effectiveness in farm-scale dispersed trials on loamy sands and very sandy loams at a fertilization level of 100 kg N/ha under the condition in the GDR comes up to 25, 40, and 22 % in winter wheat, winter rye, and potato, respectively, it totals 66 % in field grass at a fertilization level of 160 kg N/ha (SCHNEE, M., 1976). Thus nitrogen takes an important part in yield formation. On light soils, however, it is not to be excluded that fertilizer nitrogen and nitrogen originating from mineralization of organic matter in the soil will penetrate into ground and surface water. In unfavorable cases, the nitrate content in the water may exceed the limit of toxicological safeness. Hence, science is obliged to attend still more carefully to the elaboration of environmentally acceptable and protective solutions.

Consequently, the use of nitrogen fertilizer is aimed not only at reaching high yields per unit area but also at improving the utility value of the crop products and at minimizing nitrogen pollution. The realization of these aims will render the application of fertilizers, particularly of nitrogen fertilizers, highly effective.

To have the environment impaired as little as possible when carrying out fertilization operations, numerous measures to protect environment have been taken and will be taken in the GDR.

The state, society and each citizen in the GDR are obliged to protect nature and its resources. This obligation is laid down in the Constitution of this country. Therefore, state management and agricultural research bodies have been concerned with introducing, parallel to the application of increased amounts of mineral and organic fertilizers, a variety of measures contributing to a rise in soil fertility and, thus, to further improve the 'kidney function' the soil has in nature (RÜBENSAM, E., 1979) as well as continuously complete the scientific fundamentals of fertilizer use. Furthermore, it is not only a matter of balancing energy spent on the production, transport, handling, treatment, and spreading of mineral fertilizers by a high energy gain through plant yield, but of increasing this energy gain. It is started out from the fact that the use of large quantities of mineral fertilizers and organic manures constitutes an essential precondition for raising agricultural production and improving soil fertility. At the same time, the possible effects on environment, on the one hand, and the demands in the field of water management and environment protection, on the other hand, expand. Such effects have to be differentiated as direct and indirect ones.

The direct effects are insignificant after spring application of nitrogen fertilizers at the start of the growing season as, if done properly, the nitrogen generally will not be translocated to the subsoil. Experiments with small lysimeters on five sites between 1965 and 1972 revealed the N leaching to vary between 8.8 and 16.7 kg N/ha and year (below 1 m). Of these only 10 to 15 per cent accounted for fertilizer nitrogen. A certain exeption are sandy soils where nitrogen may be washed out eventually in spring if root and tuber crop are cultivated and high precipitation occurs in the period when the plants do not yet take up nutrients or do only to a small degree. The same holds true of high quantities of supplemental water from sprinkler irrigation. High rates of organic manure applied in autumn, however, may result in N translocation to deeper soil layers, particularly when slurry is used.

While properly applied mineral fertilizers generally do not have any direct influence on nutrient translocation, a direct effect may be caused at high fertilization level by 'nutrient residues' left after too high fertilizer applications or very low crop yields. This nitrogen is found in the soil in form of nitrate and, thus, is mobile.

The chance of nitrogen being built up in the soil is due to another indirect relationship with fertilization. The intensification of crop production and the increasing use of mineral fertilizers as well as of ever higher amounts of organic manures lead to a site-specific level of soil organic matter, which is an important characteristic of soil fertility. Organic manuring and soil organic matter are known to have a positive effect because they do exert a most favorable influence on the soil's physical, chemical, and biological properties. The same holds true of the cleaning efficiency, the 'kidney function' of the soil for contaminants to the environment.

As in 1977/78 129 kg N, 66.1 kg P_2O_5 and 63.4 kg K_2O were applied on average per 1 ha of farmland area in the GDR (according to Statistisches Jahrbuch der DDR 1979, economic year), fertilization has to be organized in such a way that crop yield and quality are strongly influenced and environment is impaired as little as possible. To meet these demands EDP programs have been established to an increasing extent since 1971 for the use of macronutrients (N, P, K, Mg, Ca) and micronutrients (B, Cu, Mn, Mo, Zn) and organic manures and have been put at the disposal of the GDR farms for crop production as decision aids for the planning and application of fertilizers and manures (Table 1 - Application range of the EDP-project 'Fertilization' and of plant analysis, in per cent related to the area attended to by the Agrochemical Analysis and Advisory Service of the GDR; BEER, K. and KOLBE, G., 1978).

The computation of recommendations is based on EDP programs including a variety of parameters from which decisions are derived by logical linkage of facts during the computing operation. It is possible by changing parameters and computing operations to have new scientific findings and experience of outstanding farms immediately introduced to a broad range of farms.

For mineral fertilizers and organic manures recommendations are given on quantity, splitting, time, fertilizer form, and application technique related to the respective crop in the field and the meadows and pastures, respectively. Furthermore, calculations of organic manure production and accounts of fertilizer requirements by quantity and assortment are made for planning purposes under consideration of the temporal demand of sections and departments of a farm as well as of the whole farm. Simultaneously these recommendations are further summarized and then serve the state management as fundamental material for planning the fertilizer requirements and the regional distribution of the total amount of mineral fertilizers to counties and districts as well as agrochemical centers (ACC) that have been founded as inter-farm establishments by the farms for crop production and mostly perform the spreading of mineral fertilizers. The rapid growth of the GDR agricultural production, the results obtained in research work, and the evaluation of numerous proposals of experienced workers as well as the ever increasing information demand rendered it necessary to review and improve the computing techniques and parameters of the existing EDP fertilization programs along with the current program work.

2. EDP fertilization project DS 79

The new fertilization project DS 79, programmed in PL 1 language for the EDP unit Robotron ES 1040 allowed to link the individual sub-programs (macronutrients, micronutrients, organic manuring). The latter may be computed in combination or separately. A survey of the structure of the EDP project 'Fertilization' is given in Figure 1 'Scheme of the fertilization system' (BEER, K. et al., 1978).

The fertilization project consists of the following linked sub-programmes:

- organic manuring
- mineral fertilization - macronutrients
- mineral fertilization - micronutrients

As for reasons of planning and as a basis for decisions on PK advance fertilization and liming, the fertilization recommendations must be computed already in the summer of the preceding year; the operational adaptation of nitrogen fertilization to the actual meteorological conditions forms another integral part of the fertilization project. The exact determination of the N fertilization is based on soil analyses for plant-available nitrogen content in early spring (Topical Advice on Fertilization) as to the first

N dressing, and on plant analysis as to the 2nd N dressing to winter cereals. The technological run of working out EDP fertilization recommendations is shown in Figure 2.

Figure 2 Organization of data collection, computation and output of fertilization recommendations

Data collection and provision as well as the filling in of the input documents are done under the supervision of cooperators of the Agrochemical Analysis and Advisory Service of the GDR (ACUB). ACUB belongs to the Institute of Plant Nutrition, Jena, of the Academy of Agricultural Sciences of the GDR. It has divisions in Jena, Halle, Bergholz-Rehbrücke, Dresden and Rostock. The staff members of these service divisions are responsible for advising the farms for crop production in their region. The samples of soil and/or plants as well as manures are analyzed in specialized laboratories in Jena, Rostock and Halle. The staff members of ACUB check the input documents filled in. All input data are punched in the Dresden division of ACUB.

Checking of the punched input data, running of the EDP program, and printing of the fertilization recommendations are carried out in the computer centre of the Ministry of Agriculture, Forestry and Food. Then the staff members of ACUB check the EDP fertilization recommendations, hand them to the farms and agrochemical centers, and give the necessary explanations.

To ensure a wide application range of the program, it was laid out for 207 crop species and utilization types. The crops are included in the computation as crop to be fertilized and for their properties as first and second preceding crops or catch crop. Table 2 gives a survey of the crop groups to be included.

Table 2 Crop species and utilization types covered by the EDP project 'Fertilization' DS 79 (ANSORGE, H., 1978)

The cropping form, and in several crops also the varietal type grown, as well as the intended use, are considered to further specify the fertilization recommendations.

The intended use of the harvested crops is required to consider in fertilizer application the influence of fertilization on the quality of the harvested crops.

The following uses are included:
- industrial processing of the harvested crops (e. g. malting barley, starch potato, manufacture of baby food from vegetables)
- feed and bread grain with increased crude protein content
- whole-plant harvest
- artificial drying of forage
- hay-making and feeding of fresh forage or pasturing, respectively
- ensilage
- immediate consumption of vegetables and potatoes
- storage of vegetables and potatoes
- multiplication

The effect and the dynamics of the nutrients supplied are strongly influenced by the site conditions. Therefore, the different soil properties and the climate are largely considered when computing fertilization recommendations within DS 79. In this context, it is not only the soil nutrient content being systematically determined in the GDR since 1952 on the basis of respective laws, that plays an important role. Table 3 shows the soil groups for arable land included in DS 79.

Table 3 Soil groups DS 79 - arable land (ANSORGE, H., 1979)

The first figure of the soil goes for the texture of the topsoil, the second figure for hydraulic conductivity and waterlogging (water level). Excepted are chernozem soils (soil group 4.4), half-bog soils (soil group 6.1), and bog soils (soil group 6.2).

To be able to consider the different influences of the climate on the level and effect of nutrient supply, it was necessary to define four macroclimatic zones for the farmland area in the GDR.

Climatic zone 1 = Lowlands under maritime influence in the north and the hilly country with humid, mild climate in the south of the GDR

Climatic zone 2 = Dry region and marginal areas in the middle and the southern parts of the GDR

Climatic zone 3 = Transitional region between the hilly country and the foothills up to the medium-altitude elevations of the low mountain range of the GDR

Climatic zone 4 = Elevations of the low mountains of the GDR, exceeding 500 m above sea level.

The regional distribution of the climatic zones to the GDR counties is shown in Figure 3.

Figure 3 Climatic zones - DS 79

The delimitation of the climatic zones is based on meteorological limits (Table 4).

Table 4 Meteorological limits of the climatic zones - DS 79

This macroclimatic approach necessarily includes influences of the micro- and local climates, which are the reasons for exceeding the limits quoted. These influences should be considered by assigning them to the respective climatic zone in accordance with the meteorological limits.

For the exact determination of the fertilization periods in the different GDR regions in dependence on climate and weather, four phenological zones are differentiated:

Phenological zone 1 = Region with normal start of vegetative period

Phenological zone 2 = Region with slightly late start of vegetative period

Phenological zone 3 = Region with normal start of vegetative period and very early **grain** harvest (early threshing)

Phenological zone 4 = Region with very late start of vegetative period

The structure of the flow chart of the sub-programs according to the unit assembly principle and an exact adaptation of the respective input and output information allow in DS 79 to compute separately and in combination the sub-programmes mentioned in Figure 1. Therefrom result the following possible computation systems (Table 5).

Table 5 Survey of the computation systems of the DS 79 program (ANSORGE, H. et al., 1979)

Computation systems 1 and 2 are those most frequently used by the farms for crop production. Computation system 1 'Mineral Fertilization (Macro- and Micronutrients)' serves to compute crop- and field-related recommendations for fertilization with macronutrients (N, P, K, Mg, Ca), and if results from soil analysis for micronutrients are available also for fertilization with micronutrients (B, Cu, Mn, Mo, Zn), in terms of quantity, splitting, time, fertilizer form, and fertilization technique. If micronutrients are required, feedback takes places to the use of macronutrient fertilizers containing micronutrients. Site conditions, economic factors, and the influence on the quality of the crop products are considered in the computation.

The farms have to provide data on the intended organic manuring to enable the integration of the nutrients supplied by the organic manuring and the computation of the balance for the reproduction of soil organic matter.

Computation system 2 'Organic Manuring' is used to compute the availability of the different organic manures in terms of quantity and time, and their distribution to crops and fields under consideration of factors of agronomy and cultivation, demands of environmental ecology as well as aspects of labour organization and economy. These data may also serve as input data for computing mineral fertilization. Furthermore, balances are established for the quantity and use of straw and reproduction of soil organic matter.

Of the remaining computation systems, system 6 'Nitrogen Fertilization in Spring' is of special importance for considering the problems of environment. It is intended to additionally compute recommendations for nitrogen fertilization within a short time in spring. It serves to correct changes in the cropping plan and the use of organic manures, which particularly influence nitrogen fertilization of the fields. Moreover, nitrogen fertilization is adjusted to the conditions of the preceding year (crop yield, nitrogen extraction and nitrogen residues in soil) and to nitrogen dynamics in soil during the winter months. Thus the amounts of inorganic nitrogen compounds (N_{in} = NH_4^+-N and NO_3^--N) available in the soils in early spring are considered.

The fertilization recommendations are computed by fields for the respective crop species or utilization type. The fertilizer amounts required to reach the planned yields are printed out.

The level of N fertilization is computed by means of production functions (polynomials of 2nd order) representing the relations between N fertilization and crop yield. In a special program, the yield increments reached per kg N at the respective yield level are viewed against the additional expenditures for fertilization (technological costs for N, P, and K), taking the harvesting costs for the yield increment into account. The optimum is reached when the returns for the yield increment come up to the costs for the additional expenditures required for its production. The optimal N rate (N opt.) is calculated by means of the optimal yield (Y opt.) (RÜBENSAM, H.; KUNDLER, P.; WIENRICH, B., 1972).

$$Y\ opt. = \frac{PN^2}{\left(Py - My - \frac{Ep}{Ap} \cdot Pp \cdot \frac{Ek}{Ak} \cdot Pk\right)^2 \cdot 4c} - \frac{b^2}{4c} + a$$

$$N\ opt. = \frac{-b}{2c} - \sqrt{\frac{b}{2c}^{2} - \frac{a}{c} + \frac{Y\ opt}{c}}$$

In this context, the symbols mean:

a, b, c - partial regression coefficients of the production function
PN - technological costs of N fertilization
Py - price of crop products in M/100 kg
My - harvesting costs in M/100 kg
Ep - P uptake by plant in kg/100 kg of yield
Ap - site-dependent P utilization coefficient
Pp - technological costs of P fertilization
Ek - K uptake by plant in kg/100 kg of yield
Ak - site-dependent K utilization coefficient
Pk - technological costs of K fertilization

By correcting the optimum N rates it is possible to systematically influence the crop yields and especially the quality of the crop products from certain species if there is the respective demand in national economy. The optimal N rates are not calculated from year to year, but are included as table values in the DS 79 computer program.

Crop species grown to a smaller extent are not optimized through production functions. In such cases, tables were worked out on the basis of experimental results.

Due to the strongly varying yields, the level of N fertilization to vegetables is investigated by way of balancing, the planned yields being included (GEISSLER, TH.; GEYER, B., 1976).

$N\ kg/ha = E \cdot a \cdot A + b$ where

E	is	planned yield in 100 kg/ha
a	is	N uptake by plant in kg/100 kg
A	is	factor for crop- and site-specific assimilation capacity
b	is	addition depending on vegetables species and fertilization group

The basic value of optimal nitrogen fertilization relating to cereals as preceding crop, normal meteorological conditions, and absent organic manuring is further presented by additions and subtractions for:

- yield level
- preceding crop and position in the crop rotation
- use of the crop products
- cultivation form
- nutrient supply by organic manuring to the crop or residues from the fertilization of the first crop or preceding growth
- residual effect of organic manuring to the preceding crops
- variety in vegetables, cereal plants, potatoes, and seed growing crops
- application of culm stabilizers.

The additional computation of nitrogen fertilization in the spring of the crop year includes furthermore:

- nitrogen uptake by the preceding crop in dependence on the yield level
- level of N fertilization to the preceding crop
- nitrogen residues from the preceding year, and
- N translocation during the winter months.

Considering these factors of influence on the level of the overall nitrogen requirements allows an almost full adaptation to the respective production conditions so that it is possible in almost every case to avoid damages from overdressing and stronger N translocations into the ground-water even on low-sorption soils during the growing season.

A further measure for eliminating nitrogen overdressing and leaching consists in splitting N fertilization and observing optimal application dates. Thus, it is recommended to split N fertilization into two dressings for cereal crops and sugar beet and two to four dressings for almost all vegetables, perennial forage plants (including grassland) and seed growing crops. In this way, damages from overdressing will be avoided, the quality of the crop products will be improved and strong N translocations will not occur even after heavier precipitations.

The farms for crop production receive recommendations on the optimal application dates for all fertilizer dressings (including split dressings). They are given in form of print-outs on the time spans indicated in 10-day periods and months and the respective stage of plant development. Thus it is guaranteed that even in a year when the meteorological conditions deviate much from the standard, N fertilization will be carried out at the time when the nutrients are needed and due to a rapid uptake by the plant will not be washed out to a greater extent. Recommendations on autumn N dressings of 30 kg/ha are only given for the cultivation of winter rape grown after cereals in order to ensure a sufficient juvenile development of the plants before winter. Autumn N dressings are not recommended for other crop species, nor for winter cereals and after straw manuring, to prevent stronger N translocation to lower soil layers, which may become possible particularly during mild winter months with heavy precipitation.

Calculation of P, K, and Mg fertilization is done within nutrient balancing where nutrient uptakes by the crops are viewed against nutrient supply by mineral fertilization and organic manuring under consideration of nutrient utilization and nutrient status of the soils.

At an excessive nutrient content of soil, it is recommended not to apply mineral P or K fertilization. The field will even be excluded from organic manuring supplying a high amount of nutrients, when the range of toxic action (e. g. in potassium) is reached. Soil analysis thus has a regulating function in the calculation to eventually compensate for errors occurring in balancing (e. g. errors caused by several-year deviations of the actual yield from the planned yield).

On the basis of analytical results on the lime status of soil the level of liming is determined in dependence on the soil class, humus content and the crop species as well as utilization type. The lime quanities are fixed to reach optimal soil response.

The EDP program for computing recommendations on micronutrients is structured in such a way that all influencing factors hitherto known from fertilization trials and practice, such as level, technique, time, and form of fertilization with micronutrients, are considered.

In this context, a valuation is made of the individual factors exerting a differently strong influence. Special attention is paid to both the different micronutrient requirements of the individual crop species and the supply of the soil with the respective micronutrient.

The calculation of organic manuring indicates the available amounts of the organic manures and then defines their distribution to crop species and fields. The available amounts of organic manures are determined on the basis of the given quantities or the given livestock in dependence on the type and size of livestock management during the year, housing of the animals, and storage of the organic manures. The existing stocks, supply from other farms, and delivery to other farms are taken into account.

Requirements of environmental ecology have to be considered in planning the use of organic manures, particularly of slurry. For this reason, the conditions of environmental ecology and the specific farm conditions are taking a special position amongst the complex of factors considered for the recommendations on fertilizer use (Table 6).

Table 6 Factors for fertilization recommendation on organic manuring

To have them included for each field, the following limitations may be given:

- exclusion of any organic manuring,
- confinement to solid organic manures (exclusion of liquid organic manures),
- temporary prohibition of slurry spreading during the year,
- limitation of application rates in kg/ha of total nitrogen by solid and/or liquid organic manures in various levels (100 and 200 kg N/ha, respectively)

The combination of these possibilities allows to include all relevant conditions of water management with respect to water protection zones, ground water level, inclination of slope, management, and the like in fertilization recommendations.

Fertilization recommendations are given on the basis of the
- quantity and time of organic manure production
- storage capacity
- field data
- given transport distances, and
- parameters for the use of organic manures

The fields are selected by rank order (GÖRLITZ, H., 1978).

The recommendation of fertilizer use starts out from the optimal time spans for the individual crops. In how far it is necessary to recommend manure spreading beyond these time spans, depends, first of all, on the area available for application (cropping pattern and removal of the preceding crop) and the existing storage capacity. These problems are important in connection with factors of labour organization, particularly in case of slurry application, as partially it has not yet been possible to sufficiently coordinate cropping pattern, crop rotation, storage capacity, and spreading capacities to the quantity of slurry available.

Farmyard manuring is carried out according to the known crop-specific parameters. Due to the high proportion of soluble nitrogen content, the rate of slurry application must be in accordance with the nitrogen requirements of the plant stands. It, therefore, results from the N requirements of the plant stands, the N content of the slurry, and the mineral fertilizer equivalents.(The mineral fertilizer equivalents allow the comparison between the nutrients of slurry and those of mineral fertilizers.)

A special problem arises in that the slurry must be spread over the whole year, that means in the autumn and winter months, too, as for economic reasons the storage capacity cannot have any dimensions desired and spring spreading cannot be performed within a short time for reasons of labour organization in view of the large animal houses and, hence, the high quantity of slurry produced.

To keep the N leaching as low as possible, it is recommended to mainly apply slurry on the better soils of the farm in autumn. Furthermore, the application date in the autumn months is fixed as late as possible in dependence on the storage capacity. At the same time, it is attempted to combine it with catch cropping or straw manuring. The decline in N leaching due to straw manuring is caused by an immobilization of the soil nitrogen (Table 7).

Table 7 Leaching losses after slurry manuring at various spreading dates on a Sand-Rost-Erde soil (S 5 D 20/18), 1 September, 1971, until 31 August, 1972 (potato)

Thus, straw manuring in general must be stressed as a measure to reduce N leaching attributable to nitrogen residues from fertilization or mineralization of soil organic matter. Catch cropping particularly effects a reduction of the percolation water rate through the water uptake by the plants and the N uptake from slurry application and soil (Table 7).

To reduce N leaching after autumn application of slurry, investigations have been made during the last years into the use of nitrificides. The addition of N-Serve or Cyanoguanidin to slurry inhibited the nitrification of the slurry nitrogen in incubation experiments (loamy sand, 20 °C, 50 per cent water capacity) and field trials.

3. Operational nitrogen fertilization recommendations

3.1. Topical advice on the 1st N dressing to winter cereals

As for reasons of planning and as a basis for deciding on PK advance fertilization and liming the fertilization recommendations must be computed already in the summer of the preceding year, it is only computation system 6

'Nitrogen Fertilization in Spring' which includes the meteorological conditions of the preceding year and winter. But in this case, too, it is not possible to include into the calculations the actual meteorological conditions during the growing season and their influence on fertilization. It is, therefore, necessary to adapt the N fertilization to the actual meteorological conditions later on.

Starting out from the necessity of considering the different contents of inorganic nitrogen in the soils (N_{in} = NO_3^--N and NH_4^+-N) in N fertilization to winter cereals, comprehensive investigations in this field have been carried out in the GDR since 1972. It appears that an essential factor of influence on the yield is covered when including the N_{in} content in the dimensioning of the first N dressing to cereals, and hence the relations between N fertilization and yield are described in a better way.

The N contents in soils summarized for the soil groups of the DS 79 programme in Table 8 show a marked dependence of these contents on soil, weather and the crop yield in the preceding year.

Table 8 Amounts of inorganic N (kg/ha) in the 0-60 cm layer of the 5 main soil groups in the DS 79 programme of the GDR between 1973 and 1979

To give an example it shall be stated that as compared with the average of the years, the N_{in} quantities were higher in 1977 due to the low crop yields of the preceding year, than in 1975 when heavy precipitations occurred in winter.

Since 1973, concrete comments have been made in 'Topical Advice on Fertilization' in early spring on the exact determination of the first N dressing to winter cereals under consideration of the inorganic N quantities in soil.

These comments on the correction of N fertilization are given in kg N/ha as additions to or subtractions from the first N dressings recommended in the print-outs on fertilization which are handed to the farms for crop production and the agrochemical centres. They are worked out for 21 climatic zones of the soil and all the soil groups occurring there (altogether 52 correction values). These correction values are based on the contents of nitrate and ammonium nitrogen determined every year in late autumn and early spring in a total of 1,600 soil samples from 0-30 and 31-60 cm (partially also 61-100 cm) depth in 5 fields per agrochemical centre.

As also the leaching losses after autumn application of slurry do not only depend on the soil class but decisively on the meteorological conditions in autumn and winter, these values have to be equally considered in the correction of mineral nitrogen fertilization. Thus the nutrient supply will be sufficient and the residues kept in limits. Greatest variations in N_{in} content are found on medium soils as on sandy soil the nitrate nitrogen is almost completely washed out by normal precipitations, whereas on heavy soils with high water capacity nitrogen translocation is low even after heavy precipitations. The annual differences may reach considerable values (Table 9).

Table 9 Annual differences in the soluble nitrogen content of the soil at the start of the growing season after autumn application of slurry on loamy sand

The evaluation of plot and farm-scale dispersed trials and data collection on the farm show that it is possible to reach better yield stability and to improve utilization of the existing yield potential by means of an aimed N supply to winter cereals.

3.2 Plant analysis

In the GDR, plant analysis as a measure for 'operational fertilization advice' is being carried out in winter cereals and shall be applied to other crop species (sugar beet, vegetables) in future. Under the conditions of the GDR it has been shown that the N rates required for reaching high crop yields and maximum utilization of the yield potentials, as a rule, should be split in two dressings because of the disposition of the cultivated cereal crops to lodging. This should also apply to future varieties with better resistance to lodging. Whereas the N_{in} content in soil, winter precipitation, and the soil climatic region are mainly used for exactly determining the first nitrogen dressing according to EDP fertilization recommendations, it is the plant's nitrogen content at the start of shooting that forms the basis for the exact determination of the second nitrogen dressing to winter cereals.

Sampling takes place when the cereal plants are 20 - 40 cm high and have reached FEEKES stages 4 to 7. It is jointly prepared and carried out by the farms for crop production and their agrochemical centres under the supervision of the ACUB staff members. Attention has to be paid that sufficient time is left between the first nitrogen dressing and plant sampling. The optimal time for plant analysis is given with the cereal plants reaching a height of between 30 and 35 cm.

Within 4 days the ACUB analyzes the samples for their nitrogen content and conveys the recommendation for a second nitrogen dressing to the farms for crop production.

The following standards are valid for the elaboration of the fertilization recommendation on the basis of the nutritional status of the plant:

Very high nitrogen content	0 kg N/ha
High nitrogen content	30 kg N/ha
Medium nitrogen content	N fertilization according to EDP recommendation
Low nitrogen content	"
Very low nitrogen content	"

The effectiveness of N fertilization is expected to be highest in the low to medium range of plant nutrition. Therefore the complete EDP rate is applied in this case. Very low N contents indicate N deficiency calling for immediate fertilization; an increase of the EDP rate is, however, not necessary in general, unless the EDP rate is very low (below 45 kg N/ha) or the first N dressing had been higher. In this case an addition of 10 to 20 kg N/ha may be advisable.

Very dry weather after the first N dressing may cause further corrections in the following stages of nutrition.

Deviations of the mentioned scheme for fertilization recommendations may also result from abnormal crop densities. If it is noted on the data sheet that high crude protein cereals are to be produced (without providing for a third dressing), the second N dressing is fully applied even at high N contents.

All the other factors of influence on the N regime (soil class, preceding crop, organic manuring to preceding crop and main crop, the use of culm stabilizers, sprinkler irrigation) are considered in the optimal level of the second dressing as is to be seen from the EDP programme, and generally need not be judged separately.

4. Final remarks

The introduction of the fertilization system allowed to plan fertilizer use for the whole farm for crop production as well as for each field of the farm and to further improve the effectiveness of nitrogen fertilization by means of the EDP recommendation and the operational recommendations 'Topical Advice' and 'Plant Analysis' on nitrogen fertilizer application to winter cereals. Further limitation of the possible leaching of fertilizer nitrogen is one objective of this fertilization system. A certain disadvantage of this system consists in that it is necessary to proceed from long-term mean values determined in field and farm-scale dispersed trials in elaborating EDP fertilization recommendations, and that it is not possible to exactly consider in advance the meteorological conditions which have a particularly strong influence on the effect of nitrogen fertilization. The 'operational' recommendations on the application of nitrogen fertilizers to winter cereals and in future to further crops, too, at the start of the growing season and in spring shall reduce this problem.

The EDP project 'Fertilization' and the 'operational' fertilization recommendations 'Topical Advice' and 'Plant Analysis' constitute a well proved basis for decisions to be taken by the heads of farms for crop production in the management, planning, organization and control of fertilizer use. Extensive research work has still to be done to complete the scientific character of these fundamental decision aids particularly with a view to overcome uncertainties resulting from meteorological conditions and further minimize the nitrogen losses, especially on light soils. It becomes necessary to care for the complex effect of field-related fertilization recommendations, EDP sprinkling advice, and the EDP system of pest control. To this end, it is advisable to set up optimization models for the complex interaction of the intensification factors to be able to make better use of the possible combining effects through mathematical and cybernetic methods including systems analysis, and to organize more effectively the production processes in their entirety (RUBENSAM, 1979). This will contribute to make matter circulations in nature and the relations between man and environment more efficient for the benefit of the population and the protection of nature.

References

SCHNEE, M. RÖHRICHT, CHR. HARTUNG, M. REINHARDT, W.	Auswertung ermittelter Kennzahlen zum Nachweis der Effektivität und des ökonomischen Nutzens der Düngung in ausgewählten Beispielbetrieben. Forschungsbericht 1976 des Institutes für Düngungsforschung der Akademie der Landwirtschaftswissenschaften der DDR
RÜBENSAM, E.	Wege und Möglichkeiten zur Erhöhung des Ertrags- und Leistungspotentials und seiner Ausnutzung in der Pflanzen- und Tierproduktion bei effektivem Fondseinsatz. Tagungsberichte der Akademie der Landwirtschaftswissenschaften der DDR, Nr. 177, 1979, S.21-39
-	Statistisches Jahrbuch der Deutschen Demokratischen Republik
BEER, K. HAGEMANN, O. KOLBE, G. WITTER, B. PAPER, M.	Erfahrungen bei der bisherigen Nutzung der EDV-Düngungsempfehlungen und Zielstellungen für die Nutzung des DS 79 Feldwirtschaft 10/1978, S. 440-444
BEER, K. KOLBE, G.	Mikronährstoffproblem in der Landwirtschaft und Praxis der Mikronährstoffdüngung in der DDR. Symposium 1978 der Österreichischen Düngerberatungsstelle, IV/1-24
ANSORGE, H. GÖRLITZ, H. WITTER, B. WEIDAUER, W. et al.	Düngungsempfehlungen DS 79 - Methodische Anleitung zur Anwendung des EDV-Projektes. Herausgeber: Akademie der Landwirtschaftswissenschaften der DDR und VEB Agrochemiehandel, 1979, S. 1-129
ANSORGE, H.	Die Weiterentwicklung der Düngungsempfehlungen zum DS 79 - Empfehlungen zur Makronährstoffdüngung und Kalkung. Feldwirtschaft 10/1978, S. 445-450
KRÜSMANN, H. KUNDLER, P. WIENRICH, B.	Berechnung optimaler N-P-K-Düngermengen für landwirtschaftliche Nutzpflanzen. Arch. Acker- und Pflanzenbau 16 (1972) S. 115-122
GEISSLER, TH. GEYER, B.	Die Mineraldüngung in der industriemäßigen Gemüseproduktion iga-ratgeber Broschüre 1976, S. 16-22
GÖRLITZ, H.	Berechnung der Düngungsempfehlungen für die organische Düngung und die Verbindung der organischen mit der mineralischen Düngung. Feldwirtschaft 10/1978, S. 459-463

Tables and Figures

Table 1 Application range of the EDP project 'F e r t i l i z a t i o n' and of plant analysis (in per cent related to the area attended to by the Agrochemical Analysis and Advisory Service of the GDR) (BEER, K. and KOLBE, G., 1978)

	1971	1972	1973	1974	1975	1976	1977	1978
EDP programme 'Macronutrients'	54	68	85	96	99	100	100	100
EDP programme 'Micronutrients'	-	4	5	7	14	19	28	33
EDP programme 'Organic Manuring'	-	-	-	18	46	96	90	94
Plant analysis								
Percentage of area under winter cereals	-	4	17	32	43	88	95	98

Table 2 Groups of crop species and utilization covered by the EDP project 'F e r t i l i z a t i o n' DS 79 (ANSORGE, H., 1978)

	Number of the crop species or utilization types included
Cereal crops	10
Leguminous crops	10
Oil crops	10
Fibre plants	2
Field vegetables	32
Potatoes	5
Sugar beet	5
Root crops for fodder	10
Forage plants for fodder	88
Forage plants for seed	24
Tobacco	1
Grassland	10

Table 3 Soil groups DS 79 - arable land (ANSORGE et al., 1979)

Soil group	Fine particles $< 6\ \mu m$ %	Soil class	Characteristics of arable soils
1.1	$\leq$ 7	Sand (S)	Low ground-water level
1.2	$\leq$ 7	Sand (S)	Influenced by ground-water
2.1	8 - 15	Lightly loamed sand - loamy sand (Sl / lS)	Low ground-water level
2.2	8 - 15	Lightly loamed sand - loamy sand (Sl/lS)	Influenced by ground-water
3.1	16 - 25	Very loamy sand - sandy loam (SL/sL)	Without waterlogging
3.2	16 - 25	Very loamy sand - sandy loam (SL/sL)	With waterlogging
4.1	26 - 38	Loam (L)	Wihout waterlogging
4.2	26 - 38	Loam (L)	With waterlogging
4.4	26 - 38	Loam (L)	Chernozem soils
5.1	$\geq$ 39	Clay (T)	Without waterlogging
5.2	$\geq$ 39	Clay (T)	With waterlogging
6.1		Half-bog, shallow bogs	20 - 40 cm peat 15 - 30 % organic matter
6.2		Bog	40 cm peat > 30 % organic matter

Table 4 Meteorological limits of the climatic zones - DS 79

Meteorological limits	Climatic zones			
	I	II	III	IV
(1) Height above sea level, m	0 - 350	50 - 250	250 - 500	500 - 700
(2) Precipitation, mm/year	540 - 600	480 - 580	600 - 950	900
(3) Precipitation in winter, mm/year	240 - 350	200 - 240	220 - 450	420 - 600
(4) Annual mean temperature, °C	6,0 - 8,0	7,0 - 9,0	5,8 - 7,8	5,0
(5) Number of frosty days	74 - 110	80 - 90	100 - 120	110 - 150
(6) Number of days above 10 °C	140 - 160	140 - 160	100 - 165	120
(7) Dryness index	25 - 65	20 - 35	30 - 70	50 - 100

Table 5 Survey of the computation systems of the DS 79 programme (ANSORGE, H. et al., 1979)

Computation system	Information	Print-outs
(1) Mineral fertilization (macronutrients and micronutrients)	- N, P, K, Mg, Ca fertilization - B, Cu, Mn, Mo, Zn fertilization - Balance for reproduction of organic matter	- Fertilization to crop species and fields - Summary on field and farm level - Summary regarding labour organization on farm level - Summary by crop species - Balance for reproduction of organic matter
(2) Organic manuring	- Available organic manures - Straw balance - Use of organic manures - Balance for reproduction of organic matter	- Amount of organic manures produced, straw balance - Straw removal - Organic manuring to crop species and fields - Summary on field and farm level - Summary regarding labour organization on farm level - Summary by crop species
(3) Organic manuring and mineral fertilization	- As for systems 2 and 1 - Organic manuring is immediatly included in mineral fertilization	- As for systems 2 and 1
(4) Fertilization with micronutrients	- B, Cu, Mn, Mo, Zn fertilization without any feedback to the use of macronutrient fertilizers containing micronutrients	- Application of micronutrients to crop species and fields
(5) Production of organic manure	- Amount and time of organic manure production	- Amount and time of organic manure production in the animal houses - N fertilization to crop species and fields
(6) Additional computation of nitrogen fertilization in the spring of the crop year	- N fertilization with special regard to the inorganic N content in soil	
(7) Straw balance	- Straw balance	- Straw balance

Table 6 Factors for fertilization recommendation on organic manuring

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Factors of agronomy and cultivation

- Nutrient requirements and utilization by the crop species
- Organic matter requirements of soils
- Position in the crop rotation and organic manuring to preceding crops
- Soil class and nutrient losses
- Kind, nutrient content, and amount of organic manures

Demands of environmental ecology and water management

- Limitations regarding quantity
- Limitations regarding time

Factors of labour organization

- Ridability of the ground
- Special conditions for straw harvesting
- Application methods
- Transport distances
- Time of manure production, removal of preceding crop
- Storage capacity
- Suitability of crop species for fertilization
- Given times prohibiting the application of liquid organic manure
- Kind of organic manures

Specific farm conditions

<u>Table 7</u> Leaching losses after slurry manuring at various spreading dates on a Sand-Rost- Erde soil (S 5 D 20/18), 1 September, 1971, until 31 August, 1972 (potato)

Manuring	Date of slurry spreading	Nutrient losses in kg/ha				
		N	K	Ca	Mg	P
320 kg N/ha as slurry	August	37	31	174	32	2
320 kg N/ha as slurry + 4 t of straw/ha	August	23	25	106	8	2
320 kg N/ha as slurry + manuring with green winter rape	August	12	8	48	7	1
320 kg N/ha as slurry	November	38	23	144	19	2
320 kg N/ha as slurry + 4 t straw/ha	November	28	22	77	15	1

Table 8 Amounts of inorganic N (kg/ha) in the 0 - 60 cm layer of the 5 main soil groups in the DS 79 programme of the GDP between 1973 and 1979

Soil group	1973	1974	1975	1976	1977	1978	1979
Sand	62	64	50	44	64	53	66
Lightly loamed sand and loamy sand	70	66	52	118	112	67	58
Very sandy loam and sandy loam	109	80	82	78	124	69	98
Loam	94	81	70	77	138	92	83
Chernozem soil	126	144	92	138	137	127	148

Table 9 Annual differences in the soluble nitrogen content of the soil at the start of the growing season after autumn application of slurry on loamy sand

Year	Soluble N, kg/ha, at the start of the growing season Soil layer, cm		
	0 - 30	30 - 60	0 - 60
1975	35	35	70
1976	41	41	82
1977	49	82	131
1978	62	33	95

Figure 1

Scheme of the fertilization system

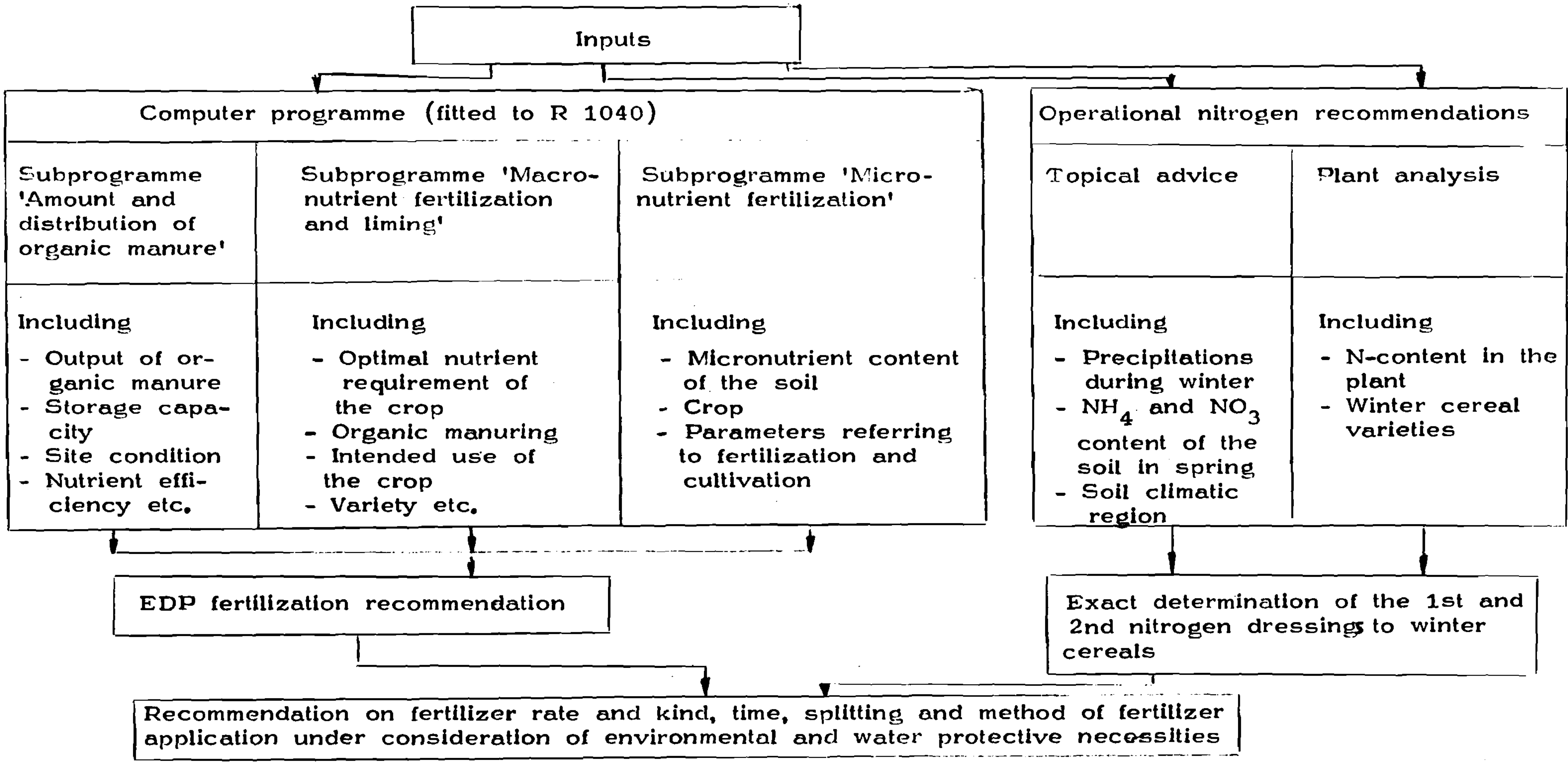
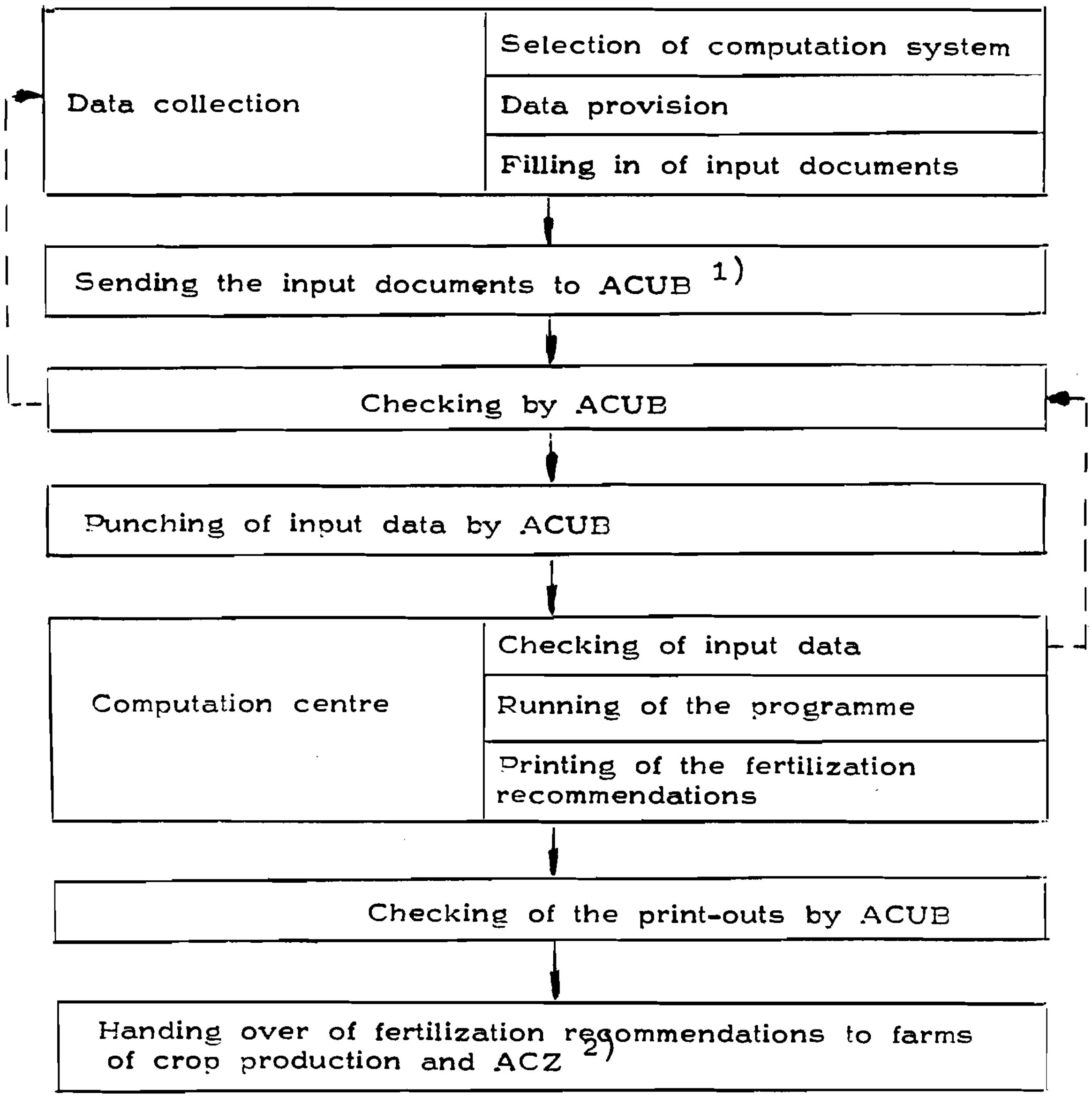


Figure 2

Organization of data collection, computation and output of fertilization recommendations



1) ACUB - Agrochemical Analysis and Advisory Service

2) ACZ - agrochemical centre

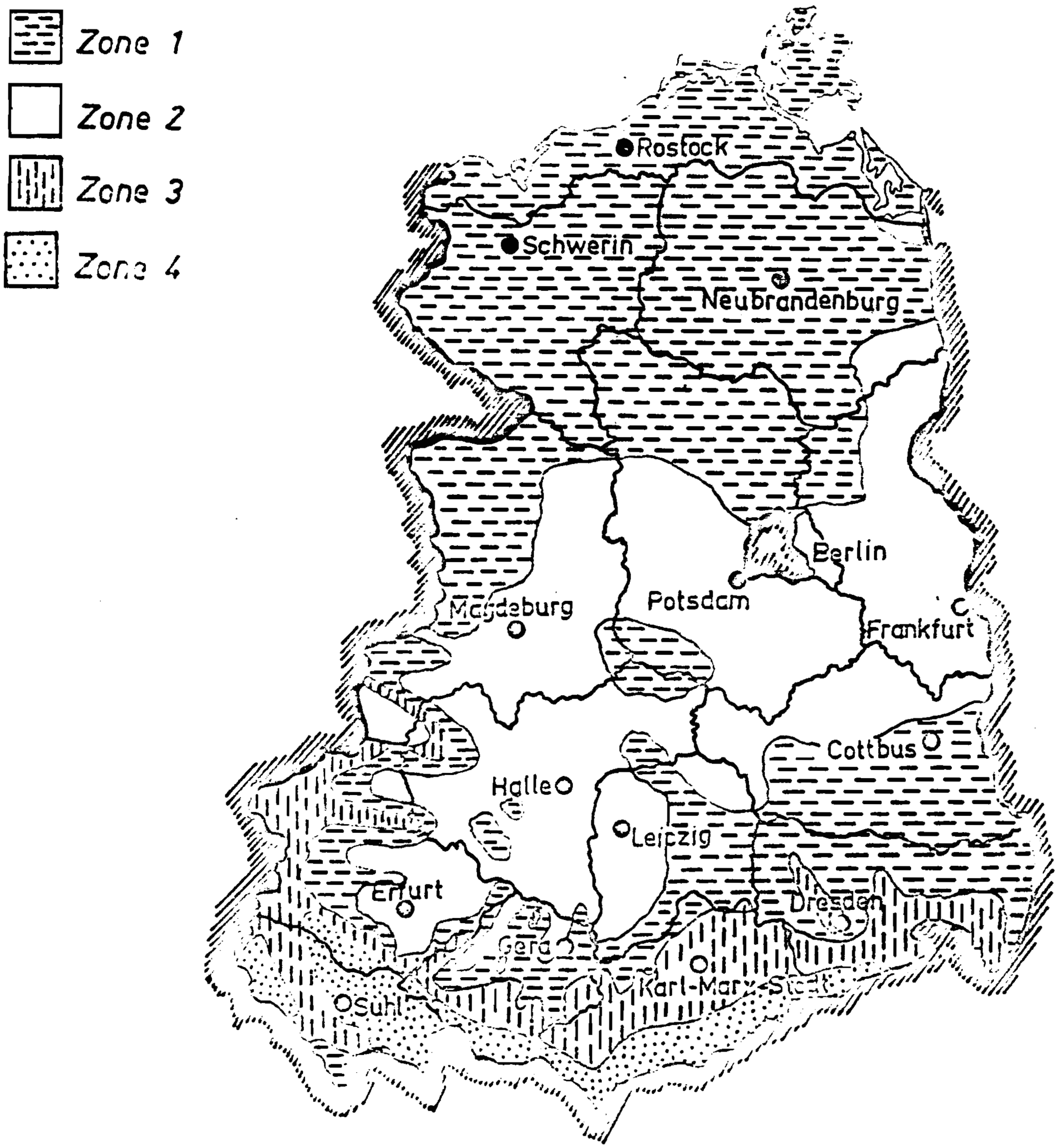


Figure 3. Climatic Zones DS 79