FERILIZATION OF ERODED SOILS

SOME PRELIMINARY RESEARCH FINDINGS AND HYPOTHESIS

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Recent and on-going research has improved our understanding of organic matter and nutrient redistribution within the landscape pattern of internally drained systems. Considerable progress has been made in the areas of pedological classification and the quantification of erosional and dispositional changes in top soil. However, the soil fertility and agronomic aspects relative to correcting or compensating for erosional influences on crop productivity, remain relatively unknown and unresearched.

This paper address the complex question of correcting and/or compensating for erosion, given current economics and technology. An historical overview of soil fertility and fertilization technology relative to spatial variability within fields is given. A technology intensive option enabling annual compensation for erosion by differential fertilization is presented along with the changes in fertility disgnostic services and research required.

HISTORIC OVERVIEW

A semi-quantitative view of erosional effects on prairie and parkland soils was held by Ellis in 1938 (Figure 1). Recognition of topsoil redistribution within the landscape pattern was frequent in the period 1938 to the present. However, soil fertility diagnostic services in Western Canada have been slow to respond to the implication of within field variability. In Saskatchewan, the introduction of a full-fledged diagnostic service in 1966 was historic in two respects:

(i) the provision of the first field specific NPK and salinity management recommendations
(ii) the decision to ignore spatial or within field variability, despite the existance of research data to the contrary.

That early historic decision to adhere to "representative sampling" and "field specific" recommendations which under or over-estimated the nutrient requirements for a large portion of each field, was understandable. Fertilizer use was in its infancy; the technology for more accurate fertilizer application was non-existent.

In the interim, some efforts have made to recognize what is now called "spatial variability" but what are mainly erosional

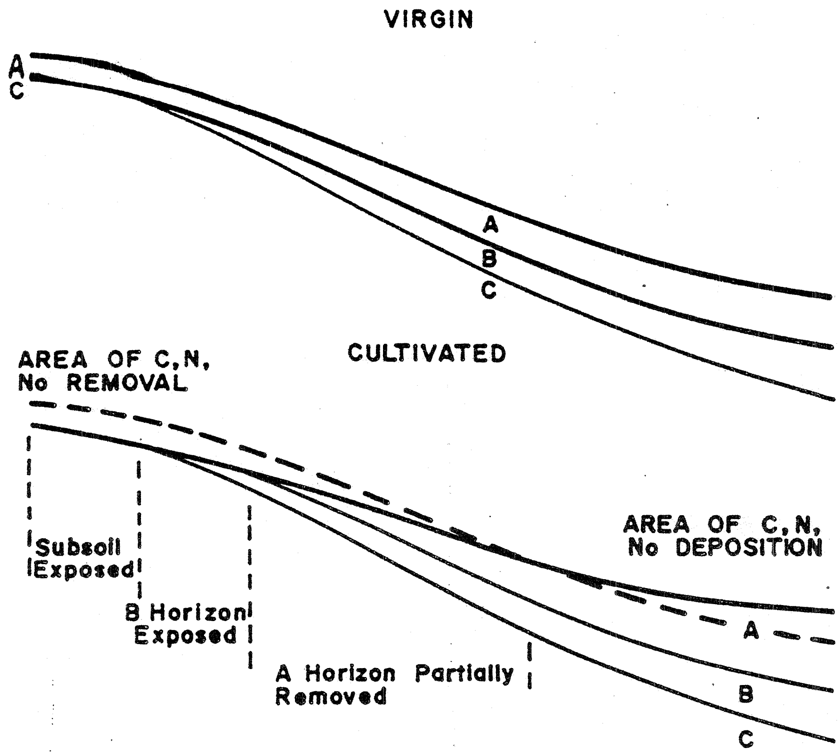

Figure 1. Schematic of differential between virgin and cultivated soil profiles (Adapted from Ellis, 1938).

influences on soil fertility and productivity. The soil fertility advisory group has sanctioned the application of massive applications of P on eroded knolls to correct accute P deficiencies. Soil testing and extension services are promoting the concept of periodic detailed soil testing involving the submission of several sets of samples from within each field to create a crude fertility map. Research on the economics and agronomics of variable rate fertilization technology has been sponsored by the provincial and federal governments (Bens 1983 and 1985).

At present, there is a "duststorm" of research and media "hype" over the issue of soil degradation and the massive amount of money needed to resolve the problem. The continuing emphasis on quantifying the exact degree and nature of soil degradation at the expense of researching the ways and means of managing the residual of our Western Canadian soil resource is disturbing. There is an urgent need to translate our existing knowledge about soil degradation and particularly soil erosion into meaningful recommendations. Perhaps, the massive amounts of tax dollars now being demanded should be directed toward "technology transfer" and applied research rather than the theoretical "wool gathering" process.

IMPACTS OF EROSION FROM APPLIED VIEWPOINT

In assessing the true economic impact of erosion on the producer and the economy it is important that the "real life" situation also be considered along with empirical research data. This approach brings the reality of current grain harvesting systems and Western Canadian growing season climate into the picture. The following is a qualitative summary of erosional impacts on the productivity and economics of the two land areas affected.

Erosional Areas

Yield/quality loss due to one or more of the following soil factors:

a. acute N, P, (K), (S) deficiencies
b. decreased water holding capacity
c. adverse soil structure
d. toxic subsoil condition

Yield/quality loss during harvest:

a. early ripening and shattering
b. pickup losses
c. weight and quality loss due to early ripening

Yield loss due to soil supplied herbicide toxicity

Inefficient water utilization.

Depositional Areas

Yield/quality loss due to one or more of the following soil factors:
- a. excess N fertility and associated vegetative growth
- b. salinity
- c. water logging and/or flooding

Yield/quality loss during harvest:
- a. late ripening and frost damage
- b. swath losses - wild life and leaching

Yield loss due to reduced efficiency of soil applied herbicides

Inefficient water utilization.

Thus, remedial measures must inherently attempt to reverse the effect of topsoil redistribution to be truly effective at the "pocket-book" level. Specifically, with respect to fertility, remedial measures must permanently or annually reverse the N imbalance between erosional and depositional areas within the field unit.

CORRECTING AND/OR COMPENSATING FOR SOIL EROSION

Given our current knowledge of erosional/depositional influences on topsoil and hence productivity within the landscape pattern, a simplistic examination of the ways and means of correcting and/or compensating for erosion is useful.

The list of practical alternatives ranging from capitol intensive to technology intensive is limited. Three management options are readily apparent at this time:

1. Mechanical replacement of topsoil,
2. Massive application of nutrients and organic matter to eroded areas,
3. Differential fertilization (and herbicide application).

The relative merits and demerits of these options are outlined as follows:

(A) Mechanical Replacement of Topsoil

- eliminates economic losses in both erosional and depositional areas.
- represents a permanent solution when coupled with adequate conservation measures
- is compatible with P.F.R.A. mentality and capability
- capitol intensive, i.e. expensive
- requires detailed soil fertility (Organic Matter) mapping service.

(B) Massive Nutrient/Organic Matter Application

- temporarily eliminates economic losses in erosional areas
- semi-permanent solution
- compatible with livestock industry scenario
- capitol intensive and limited to livestock regions
- does not eliminate economic losses in depositional areas
- not applicable to Nitrogen

(C) Differential Fertilization (& Herbicide Application)

- increases economic returns in both erosional and depositional areas
- leads to a permanent solution over time when coupled with conservation practices.
- applicable to all nutrients including N
- compatible with high technology trend in agriculture
- technology intensive, i.e. inexpensive R & D and technology transfer required
- requires detailed soil fertility (Organic Matter) mapping service.

ERODED SOIL FERTILIZATION

Research of an applied interdisciplinary nature on differential or variable fertilization with emphasis on N has been initiated by Agriculture Canada via the ERDAF program[1] through the DSS contracting system. An agronomic model has been evolved to enable the annual, systematic and continuous variation of fertilizer N within the field unit. The overall system required to impliment variable rate nitrogen fertilization (VRNF) is depicted in Figure 2.

The fundamental hypothesis governing the agronomic model and the integral N mapping system are of interest to this workshop. It should be noted that this model depends on the existing field specific N recommendations generated by services such as the Saskatchewan Soil Testing Laboratory for a "benchmark" rate. It is designed to modify that rate and thereby adjust for annual variations in residual NO_3-N, grain prices, fertilizer costs etc.

Fundamental Hypotheses

A review of the research literature on N fertility and productivity on eroded prairie and parkland soils led to the hypothesis that:

> "The key to correcting or compensating for erosional influences on N supplying power lies in the evaluation of the differential (dQn) between equilibrium (virgin) and current quantities of total and/or minerizable N in the rooting zone."

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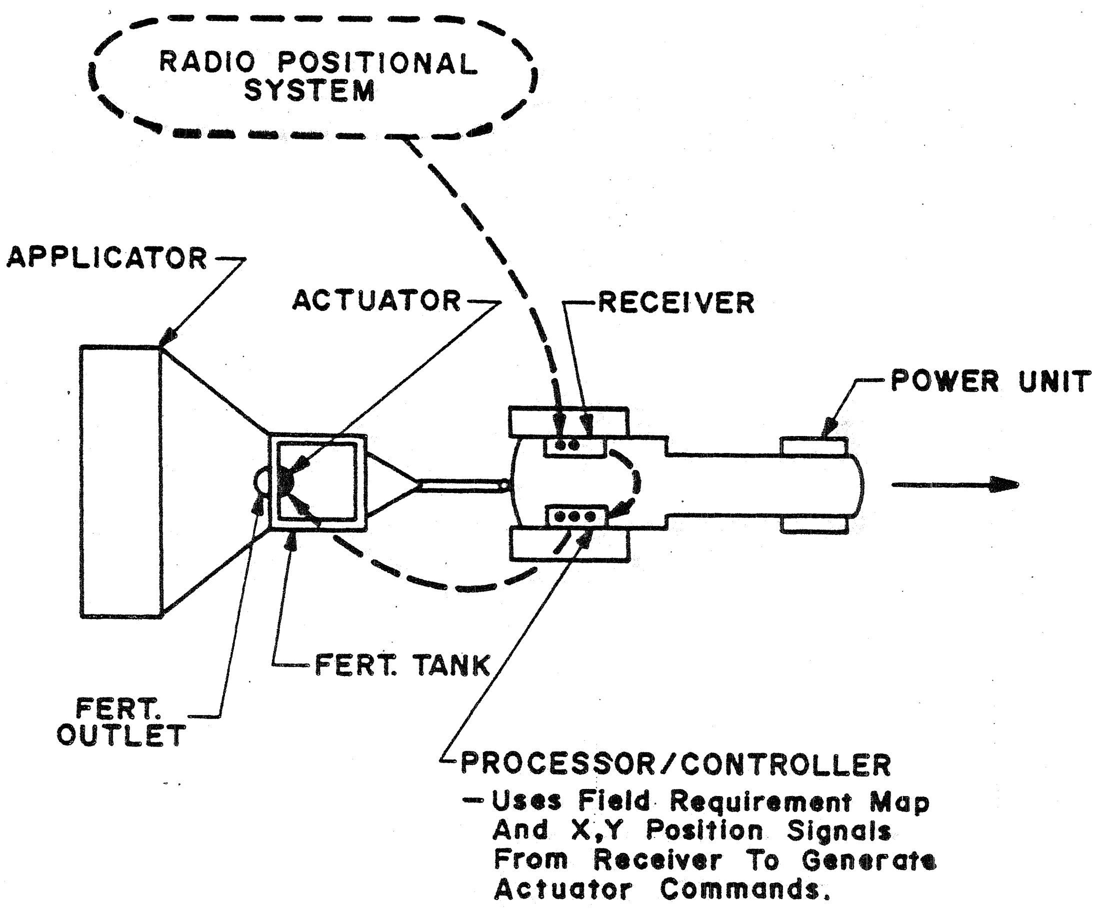
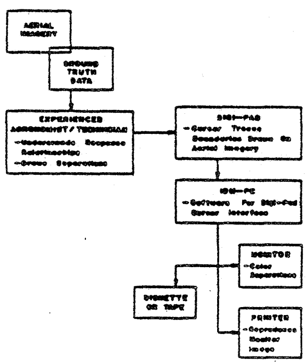
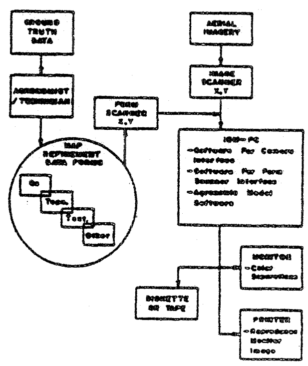
[1]ERDAF is Energy Research and Development in Agriculture; National Energy Program.





Mannual FRM



Automated FRM

Figure 2. Schematic of VRNF software and hardware with two alternative means of generating FRM diskettes or tapes.

This theory applies to both erosional and depositional areas within the field.

The search for a reasonable mechanism of deriving dQn on an empirical basis led to the formulation of a second hypothesis namely that:

> "The differential between potential and N dependent productivity within a field relative to an unchanged benchmark site which is sampled annually for supplemental N can be converted to a factor which is added to (or subtracted from) the benchmark N rate."

The following simple equations were evolved for differential productivity (dP) and the field requirement map (FRM) factor which directly controls the VRNF hardware.

$$dP = PP - NP \text{ ---------} (1)$$

$$FRM = dP \times NE \text{ ---------} (2)$$

Where:

PP = potential productivity
NP = current N dependent productivity; other nutrients sufficient
NE = Nitrogen efficiency factor; units of N per unit of grain.

The effect of slope position *per se* i.e. micro-climate on potential yields within the field is accounted for by the empirical nature of PP and NP and the adjustment of NE.

SUPPORTING CONCEPTS AND SYSTEMS

The application of this theory at the field level requires concepts to deal with degree of erosion and deposition and the quality of the eroded profiles as well as a N fertility mapping system:

Classification of Eroded Soils

A review of recent and past literature on the subject led to the formulation of the following system which illustrated diagrammatically in Figure 3. Three slope positions were segregated into eight erosional/depositional classes. In essence, the erosional/depositional character of a cultivated field is segregated into three types which correspond closely to the shape of the typical hillslope:

1. Erosional - Convex area,
2. Non-erosional - Inflection Point,
3. Depositional - Concave area.

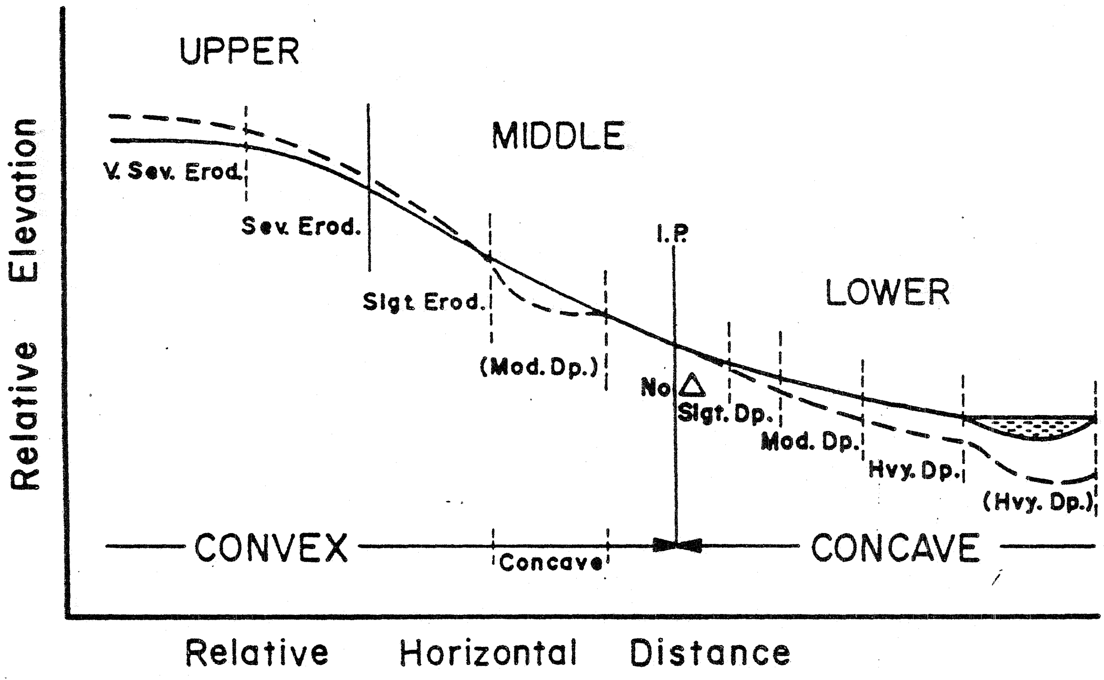


Figure 3. Eroded Soil Classification System - as applied to a typical internally drained topographic sequence.

Erosional, convex areas have characteristically shallow profiles usually described as Regosolic, Calcareous or Shallow Orthic in the Canadian Soil Classification System. Depositional, concave areas have deep profiles, often eluviated (leached) and usually described as Deep Orthic, AB Orthic or Eluviated by pedologists. Depressional sites (sloughs) within the concave areas are described as Gleyed Eluviated or Gley Orthic.

The classification system and definition devised for the three types are as follows:

A. Erosional Types

Erosional Types	Degree of Erosion (% of Topsoils Removed)
Very severe	75 - 100
Severe	50 - 75
Moderate	25 - 50
Slight	0 - 25

B. Non-erosional Types

These areas exhibit no net change in topsoil thickness and quality other than that associated with other ongoing soil degradation processes.

C. Depositional Types

Depositional Types	Degree of Deposition (% Increase in Topsoil Thickness)
Slight	0 - 33
Moderate	33 - 67
Heavy	67 +

Profile Quality

The relative effect of erosion on residual potential productivity depends on the intrinsic quality of the subsoil to serve as "ersatz" topsoil. Three profile groups are defined for prairie and parkland regions:

Profile Group	Description
A	Subsoil is similar to original topsoil except for lack of organic matter. These profiles exhibit good productivity when adequately fertilized and have good water holding capacity. Favourable characteristics to a depth of 90 cm (36 inches) or more.
B	Subsoil is different from original topsoil in that one or more adverse chemical or physical properties limits potential productivity even when adequately fertilized. Adverse features include: high bulk density, salinity, carbonates and pH, water holding capacity, aeration etc.

C Subsoil is highly unsuitable for crop growth due to severe physical and/or chemical properties as listed for B or due to coarse texture or presence of bedrock.

3. N Fertility Mapping Systems

Given the foregoing classification systems for eroded landscapes and profiles and the FRM reference tables generated by the model, mapping of N fertility on field basis culminating in the generation of a digitized map compatible with micro-processing software, can be performed. Three distinct stages can be identified in the mapping process:

1. Base map Generation (Office)
2. Ground Truthing & Soil Analysis (Field and Laboratory)
3. Data Integration & Manipulation

The activities within these stages would require a skilled technician working under the supervision of a qualified soil scientist. The system is illustrated conceptually in Figure 4.

Function and Output of the Model

The function and output of the model are illustrated below for a medium textured glacial till in the Chernozemic Dark Brown soil zone. Potential (PP) and N dependent (NP) productivity data were extracted from a variety of data sources including work on eroded soils recently summarized at Lethbridge (Doormaar, et al., 1985).

The graphical derivation of dP and the calculation of FRM factors using NE = 6, 5 and 4 lb N per bus. for upper, middle and lower slope positions respectively, is illustrated in Figure 5.

The resulting three dimensional matrix of reference FRM factors is given in Table 1. These reference factors are utilized directly in the mapping process noting that modification for the following surficial factors is also necessary:

1. textural variation
2. salinity
3. stoniness
4. excessive slope
5. susceptibility to flooding

RESEARCH AND EXTENSIVE PRIORITIES

In assessing the diagnostic and research requirements needed to impliment practical mechanism of correcting and/or compensating for erosional effects on soil productivity it is readily apparent that:

1. Traditional Soil Testing services need to address within field soil variability via a permanent fertility mapping option.

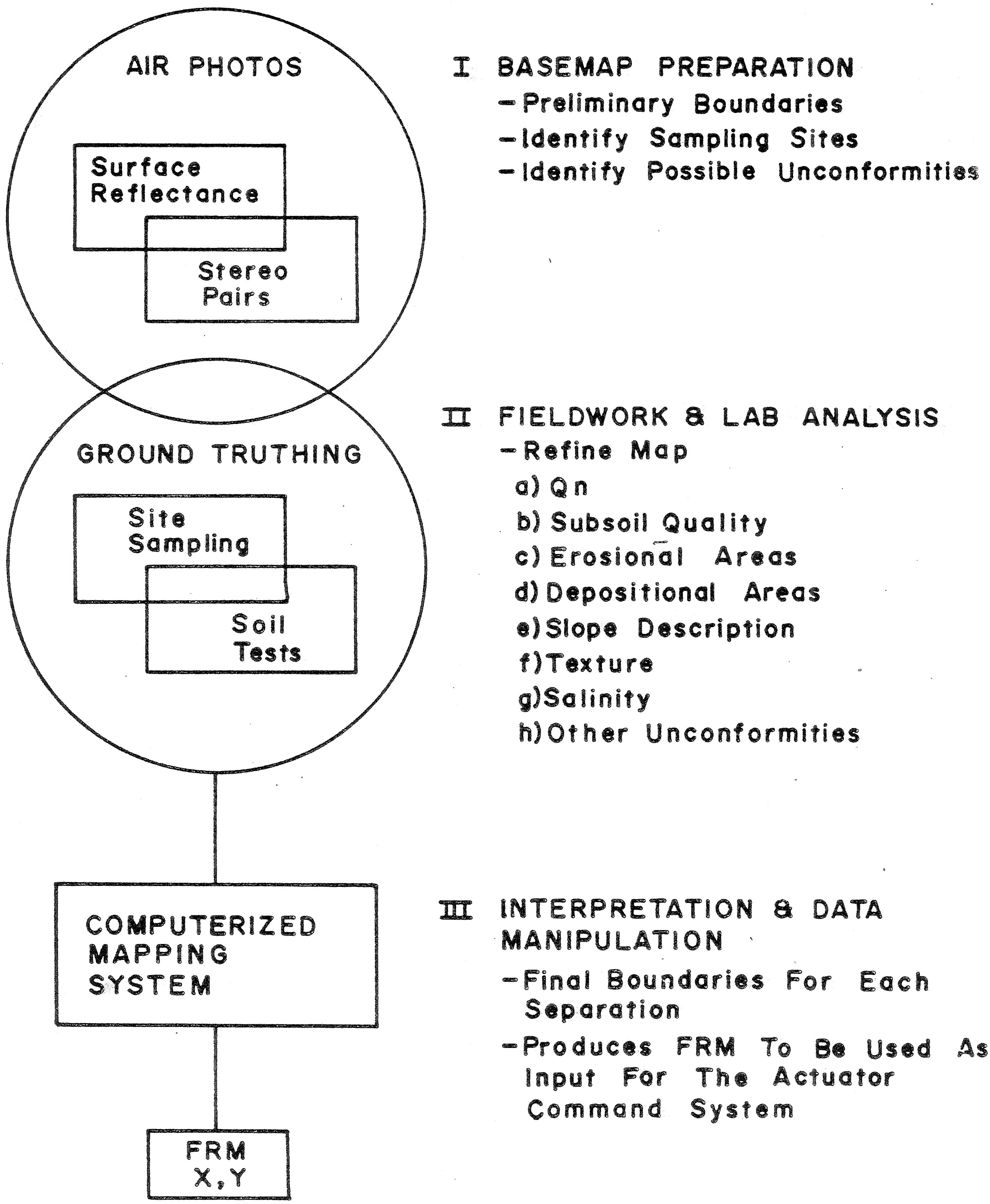


Figure 4. Conceptual N Fertility mapping procedure for VRNF technology.

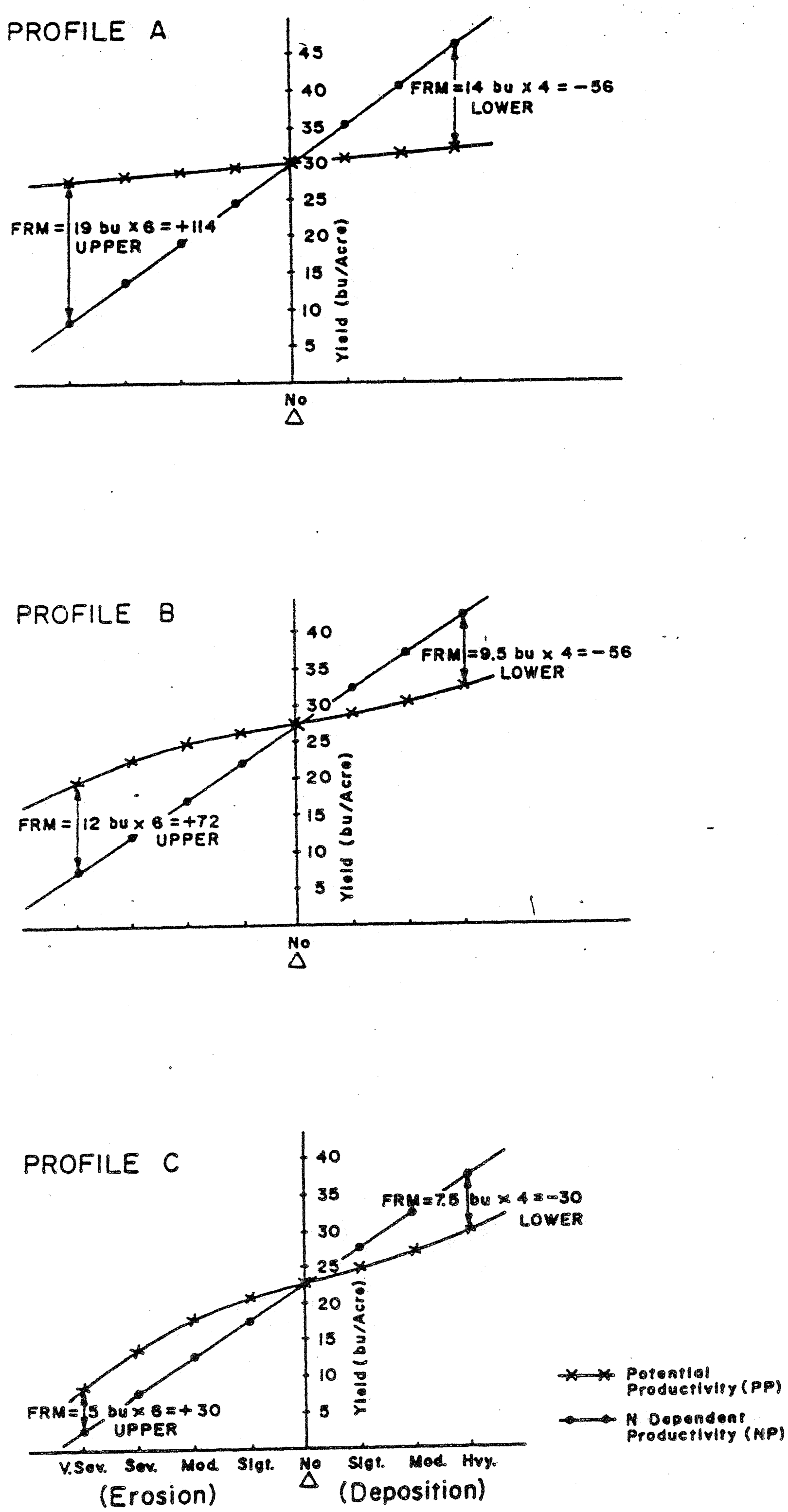


Figure 5 The relationship between potential and N dependent productivity for the various erosional/depositional classes and profile groups for a medium textural glacial-till soil in the Chernozmic Dark Brown soil zone. Also, the derivation of FRM factors for upper and positions within field units.

TABLE 1. Field Requirement Map (FRM) factors for the various erosional/ depositional, profile classes and slope positions in a medium-textured glacial till in the Chernozemic Dark Brown Soil Zone.[1]

Slope Position	FRM FACTOR (lbN/Ac)							
	Erosional Class					Depositional Class		
	V Sev	Sev	Mod	Slight	No △	Slight	Mod	Hvy
					PROFILE A			
Upper	114	81	60	30	0	-30	-60	-84
Middle	95	68	50	25	0	-25	-50	-70
Lower	76	54	40	20	0	-20	-40	-56
					PROFILE B			
Upper	72	60	48	33	0	-24	-39	-57
Middle	60	50	40	28	0	-20	-33	-48
Lower	48	40	32	22	0	-16	-26	-38
					PROFILE C			
Upper	30	33	33	24	0	-18	-33	-45
Middle	25	28	28	20	0	-15	-28	-38
Lower	20	22	22	16	0	-12	-22	-30

[1]The FRM factor for Upper, Middle and Lower slope positions were derived using NE = 6, 5 and 4 lb N/Bus. respectively.

2. Research emphasis must be shifted from theoretical post mortems towards applied research which will enable correction of and/or compensation for the problem.

3. The rate transfer of existing technology is drastically slower than the rate of technology generation.

To be specific, it is recommended that a pilot soil fertility mapping project be initiated in the summer of 1985 and that future fertility research trials in Saskatchewan be designed to include erosional/depositional profile quality effects.

The adoption of these recommendations would place Saskatchewan in the vanguard of eroded soil management and/or reclamation. It would also replace the ad nauseum clamour about soil degradation with positive, productive initiatives.

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