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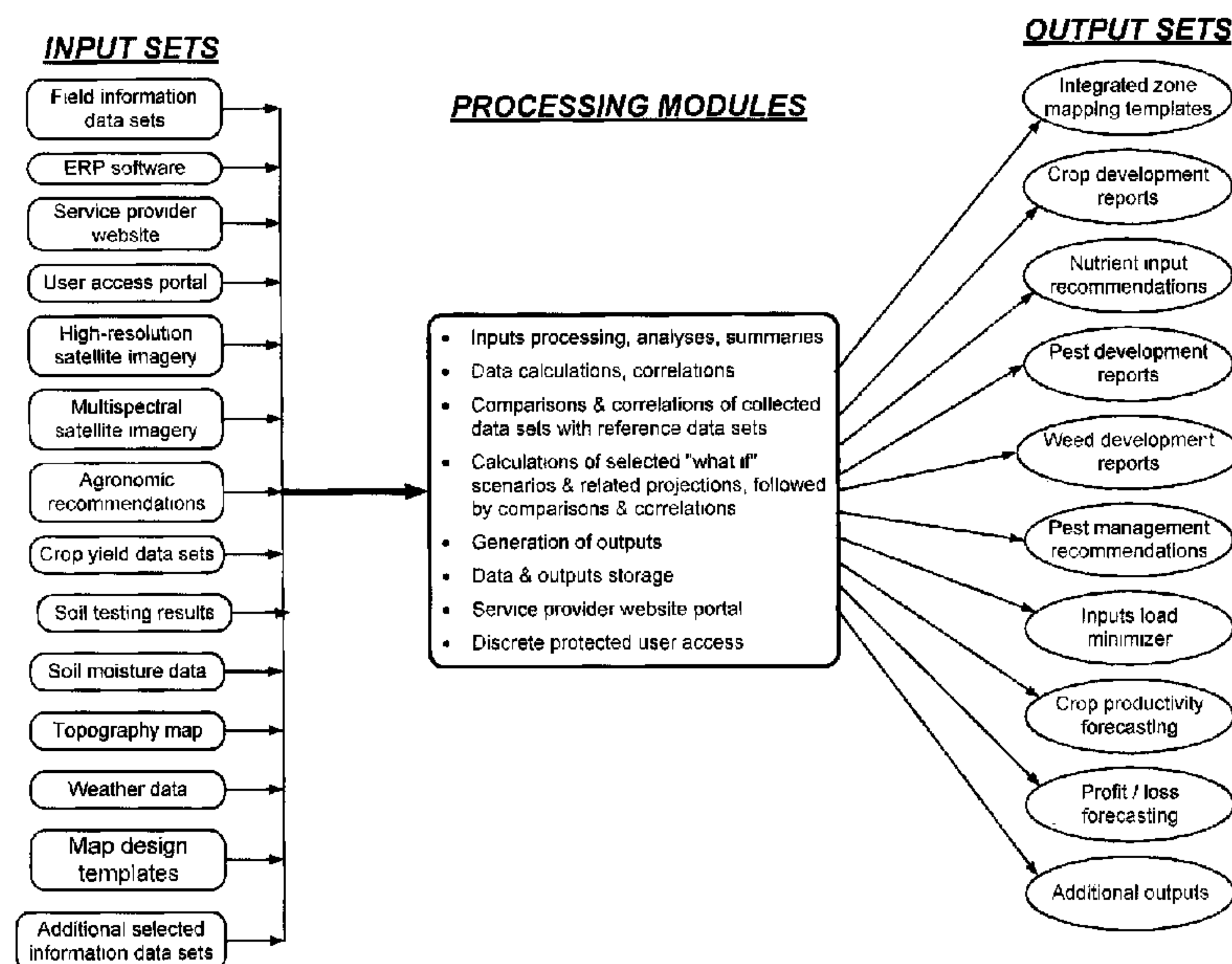
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(54) Titre : INTRANTS VARIABLES CIBLES PROPRES A UN TYPE DE CULTURE, METHODE DE PRESCRIPTION ET SYSTEMES CONNEXES

(54) Title: VARIABLE ZONE CROP-SPECIFIC INPUTS PRESCRIPTION METHOD AND SYSTEMS THEREFOR



(57) **Abrégé/Abstract:**

Methods and systems for providing variable zone-based crop inputs prescriptions for optimized production of selected crops in selected agricultural fields wherein each field comprises a plurality of soil management zones. The crop inputs prescriptions may include one or more of fertility inputs prescriptions, pest management inputs prescriptions, and prescriptions comprising combinations of fertility inputs and pest management inputs. The methods comprise incorporation, analyses and correlations of selected satellite imagery with selected crop production parameters including soil sample analyses, agronomy recommendations, historical crop production records, and historical weather data. The methods and systems are suitable for no-till field crop production practices and also, for crop production where the soil is tilled prior to seeding. The methods are adaptable for integration of real-time weather forecasting data to enable adjustments in deliveries of selected inputs during a prescribed growing cycle.



ABSTRACT:

Methods and systems for providing variable zone-based crop inputs prescriptions for optimized production of selected crops in selected agricultural fields wherein each field comprises a plurality of soil management zones. The crop inputs prescriptions may include one or more of fertility inputs prescriptions, pest management inputs prescriptions, and prescriptions comprising combinations of fertility inputs and pest management inputs. The methods comprise incorporation, analyses and correlations of selected satellite imagery with selected crop production parameters including soil sample analyses, agronomy recommendations, historical crop production records, and historical weather data. The methods and systems are suitable for no-till field crop production practices and also, for crop production where the soil is tilled prior to seeding. The methods are adaptable for integration of real-time weather forecasting data to enable adjustments in deliveries of selected inputs during a prescribed growing cycle.

TITLE: VARIABLE ZONE CROP-SPECIFIC INPUTS PRESCRIPTION METHOD
AND SYSTEMS THEREFOR

FIELD OF THE INVENTION

5 This invention relates to methods for managing agricultural crop production in large fields. More particularly, the invention relates to methods and systems for prescribing options for variable fertility and pest management inputs for optimizing crop production in selected agricultural fields.

BACKGROUND OF THE INVENTION

10 Increasing demands for increased efficiencies in crop production have resulted in the development of new agricultural production management tools, methods, and systems. Adoption of these tools has enabled significant improvements in crop yields harvested on a per-acre basis. However, the efforts required for maximizing crop yields are difficult, time consuming, and costly because the characteristics of farmlands vary from acre to acre. This variance is due to a variety of factors including among others physico-chemical factors such as soil topography, soil
15 nutrient availability, and environmental factors related to weather conditions particularly precipitation and temperature. Agricultural farmland productivity is also affected by the types of crops produced, their fertility requirements and their optimal environmental growing requirements. A constant challenge in all crop production management strategies is timely pest detection and control.

20 Current agronomic production strategies are focused on intensive fertilization to achieve maximized crop yields on individual fields. Such strategies require understanding of various physico-chemical characteristics of individual fields that could significantly affect crop yields. Agricultural lands are typically comprised of several different soil types, each of which may be categorized according to differences in soil texture, soil profile characteristics, soil chemistry,
25 and organic matter content. Some fields contain one dominant soil type that covers the majority of the field area with the remaining area made up of other different soil types. These other soil type areas are distributed around the field in various locations and have irregularly shaped boundaries, which often, but not necessarily, correspond to low or high spots. Often, a field

contains a plurality of irregularly distributed interfacing soil types. Although any given plot of land or field may include many different soil types, its potential productivity and related fertilization requirements are additionally affected by post-production-cycle residual nutrient levels remaining in the soil matrix profiles throughout and about the fields. Residual soil nutrient levels can vary considerably within a single field. For example, residual nitrate nitrogen levels can vary from about 0 to 200 lbs/acre or higher. According, it would be unusual if a field did not include at least two substantially different soils having substantially different fertilization requirements. Present methods generally determine nutrient requirements by taking soil samples from different areas of the field in a grid configuration in reference to yield data or multispectral satellite imagery. Characteristics such as soil composition and type comprising each soil sample are quantified and summarized. The depth and thickness of soil horizons and their properties can vary immensely within a landscape, and even within a given field. If a critical soil property, such as nutrient and water holding capacity or carbon content, is to be assessed within a given field or area, then it is critical that the vertical and horizontal distribution of such properties be determined accurately. When a soil core is collected, the number of sections analyzed in the sample limits the vertical resolution of the soil property assessment at that location. This is due primarily to the high cost and time expenditure associated with soil sample collection, preparation, analysis, and recording procedures. For example, if one producer managing farmland on the order of several thousand acres would require the collection and analyses of hundreds of soil samples from throughout their fields for the purpose of determining the pluralities of soil characteristics for which nutrient input requirements must be determined. Extracting and analyzing this multitude of soil samples is cost prohibitive and does not provide a viable method for maximizing agricultural output. Typically, only a few locations across a landscape are chosen for core sampling, and only a few sample sections are removed from each core for analysis. This limited vertical soil information results in errors when attempting to model the spatial distribution and volume of soil properties across a landscape. Furthermore, the grid method may unintentionally allow a varied number of soil types and elevations to be included within a single area due to the irregularity in shape of the different areas of the field. This is also problematic.

The type of the crop to be grown in a field will also significantly affect the fertilization requirements for maximal production of the crop. For example, protein and test weight for wheat

can range 2.5 percent in a single 40-acre field. The yield can vary as well. Typically, yields range from 50 percent less than the mean to 50 percent greater than the mean. Most applied nutrient amounts are determined by the expected yield of the crop. Therefore, it is important to determine yield potentials prior to application of fertilizers. Ideally, each of the individual areas of different soil should be treated independently for the purpose of applying seed, fertilizer, or other items to the field. Current practices are to prescribe items, such as seed and fertilizer, to the entire plot of land or section of the land, if using the grid method, according to the needs of the most deficient soil, or according to the averaged requirements of the different soils. Such practices commonly employ satellite imagery in combination with GIS software (i.e., geographic information system) or alternatively GPS software (i.e., global positioning system) for detecting and mapping selected fields, and for determining various attributes such as topography, estimations of soil moisture levels based on the brightness of the soil in high-resolution aerial satellite imagery, and estimations of a "normalized difference vegetable index" (i.e., NVDI) based on biomass extrapolations derived from multispectral satellite imagery. Such practices typically integrate the results of soil sample analyses with data derived and extrapolated from satellite images for preparation of soil fertility input recommendations that provide specific fertilizer input suggestions for each management zone within the field, based on field-averaging approaches for maximizing a crop yield.

Other problems encountered with the current agricultural production management tools, methods, and systems used for maximizing crop yields relate to recommendations prepared in reference to optimal growing conditions. Unexpected weather patterns occurring during the crop production cycle often reduce the beneficial effects of fertility inputs on subsequent crop growth and development. Crop plants are typically stressed significantly during extended periods of drought or alternatively excessive moisture, and during extended periods of unusually cold temperatures or alternatively high temperatures. Such stresses generally reduce plant metabolic rates and may have long-term debilitating effects of their physiological performance, thereby reducing the amounts of the applied fertilizers that are taken up by the plants. Consequently, in such stressed growing conditions, significant amounts of anionic macronutrient salts are leached away from the soil profiles while the cationic forms tend to accumulate in the upper soil horizons. Atypical weather conditions are commonly accompanied by pest infestations of the stressed crops that further reduce crop yields and add to the growers' production costs.

SUMMARY OF THE INVENTION:

The exemplary embodiments of the present invention relate to methods and systems for providing variable zone-based crop inputs prescriptions for optimized production of selected crops in selected agricultural fields wherein each field comprises a plurality of soil management zones. The crop inputs prescriptions may include one or more of fertility inputs prescriptions, pest management inputs prescriptions, and prescriptions comprising combinations of fertility inputs and pest management inputs. The methods and systems are suitable for no-till field crop production practices and also, for crop production where soils are tilled prior to seeding. The methods are adaptable for integration of real-time weather forecasting data to enable adjustments in deliveries of selected inputs during a prescribed growing cycle.

An exemplary method according to one embodiment of the present invention relates to the acquisition of a plurality of selected input data sets pertaining to a contemplated production of a selected agricultural crop. Suitable input data sets include at least among others, satellite imagery and/or aerial photographs, encompassing one or more selected agricultural fields, topographical maps, physico-chemical data generated from analyses of pluralities of soil samples collected within and about the selected agricultural field(s), historical crop yield data, and reference agronomic data pertaining to optimized production of a selected crop species. The satellite imagery is processed to determine and delineate a plurality of plant production zones based on detected and calculated differences in ranges of plant biomass densities about the agricultural field. The plant production zones are grouped into soil management zones based on the similarities of their soil physico-chemical profiles. For each of a set of selected crop inputs, a suitable quantity of a crop input to be applied to each of the soil management zones is calculated as follows. First, the residual level of a selected crop input in a selected soil management zone is determined from the previously produced physico-chemical profile for that soil management zone. The residual level of the selected crop input is then compared to a suitable reference data set pertaining to agronomic recommendations for optimal production of the selected crop. The difference between the reference data set and the residual level of the crop input in the plurality of soil samples collected from the soil management zone is the amount to be prescribed. An exemplary crop inputs prescription thus prepared may include prescriptions for one or more

selected macronutrients and nutrients for each soil management zone comprising the agricultural field.

According to one aspect, historical production and yield data collected from the agricultural field comprise suitable input data sets for comparisons with the suitable agronomic reference data sets for the purposes of adjusting, tailoring and optimizing the crop inputs prescription. The historical data may comprise records from a single growing season, or alternatively, records from a plurality of growing seasons. It is suitable for the data records from a single growing season to be used as a single data set. However, it is optional if so desired to prepare an averaged set of historical production data from a plurality of production seasons.

According to another aspect, historical weather data sets pertaining to the historical production and yield data collected from the agricultural field comprise suitable data sets for incorporating into the processing, comparisons and correlations with other input data sets. For example, it is useful to identify and correlate production data sets from growing seasons wherein certain environmental stresses such as drought, moisture, and temperature significantly affected crop productivity and yields, and then correlating the yields of such stress-affected crops to the reference agronomic data set, as part of the prescription development processing steps.

Some exemplary embodiments of the present invention relate to variable zone-based crop inputs prescriptions for optimized production of each of a plurality of selected crops in a selected field that comprises a plurality of soil management zones for use in assisting crop production management decision-making regarding selection of a crop for production in the agricultural field.

Another exemplary embodiment relates to methods and systems for providing targeted zone-based crop inputs prescriptions for delivery of pest management strategies and products to the crop during the production cycle. Such methods generally comprise additional steps of inputting data sets pertaining to optimal environmental conditions suitable for field application of selected chemical pesticides and biological pesticides relevant to the production of the selected crop, and also, to inputting data sets pertaining to sub-optimal environmental conditions for the application of these pesticide products and the effects on pesticide performance. Additional input steps may include inputting of real-time weather conditions and forecasts, and optionally, the

severity of pest incidence and distribution throughout the agricultural field. The processing steps will select a suitable pesticide product for application and provide information outputs pertaining to weather forecast-based time windows suitable for application of the selected pesticide product.

Other exemplary embodiments of the present invention relate to methods and systems for
5 storing inputs data sets, processing modules and output sets in suitable protected databases that are accessible, and optionally manipulable, by qualified users. Certain aspects relate to wireless transmission of the inputs data sets and outputs sets to a user for reception by suitable devices exemplified by laptop computers, hand-held data transmission and receiving PDA devices (i.e., personal digital assistants). Other aspects relate to correlation of the outputs sets pertaining to
10 prescriptions for crop inputs to be applied to specific soil management zones within the agricultural field, with GPS positioning coordinates to facilitate computer-controlled applications of the crop inputs by suitably equipped field equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described in conjunction with reference to the following
15 drawings in which:

Fig. 1 is a schematic block diagram summarizing exemplary inputs, processing modules and outputs according to an embodiment of the present invention;

Fig. 2 is a schematic flow chart outlining an exemplary method and related system of the present invention;

20 Fig. 3 is a schematic flow chart outlining another exemplary method and related system of the present invention;

Fig. 4 is an exemplary high-resolution aerial satellite imagery encompassing an agricultural field;

Fig. 5 is an exemplary multispectral satellite imagery of the agricultural field from Fig. 4;

25 Fig. 6 is an exemplary soil sampling design template superimposed on the multispectral satellite imagery from Fig. 5;

Fig. 7 is an exemplary high-resolution aerial satellite imagery encompassing another agricultural field;

Fig. 8 is an exemplary multispectral satellite imagery of the agricultural field from Fig. 7; and

5 Fig. 9 is an exemplary soil sampling design template superimposed on the multispectral satellite imagery from Fig. 8.

DETAILED DESCRIPTION OF THE INVENTION

The methods and systems of the present invention for providing variable zone-based crop inputs prescriptions for optimized production of selected crops on selected agricultural fields, generally relate to collection of selected input data sets, processing and correlating the data sets, and producing from the correlated data sets, output sets of information relevant for assisting agricultural crop production management decisions for selecting individual fertility and/or pest management inputs for optimizing crop production and for the timing of the applications of the selected inputs. The methods and systems of the present invention are generally referred to herein as variable zone-based crop inputs prescriptions, The variable zone-based crop inputs prescriptions are suitable for no-till agricultural crop production and for crop production systems wherein soils are tilled prior to sowing.

As shown in Fig. 1, some embodiments of the present invention generally relate to the collecting and inputting of a series of data sets pertaining to a service provider, a user, to selected sets of information and/or data relating to a selected agricultural field, and to selected reference data sets. Suitable input data sets pertaining to a selected agriculture field generally comprise at least some selected information exemplified by imagery, physico-chemical data for the soil zones comprising field, historical crop production and yield data for the agricultural field, agronomic recommendations for production of one or more selected field crops, and historical weather data.

Suitable imagery data is exemplified by and/or derived from high-resolution aerial imagery, panchromatic satellite imagery, multispectral satellite imagery, hyperspectral satellite

imagery, light detection and ranging (LIDAR) data, digital elevation model (DEM) data, topographical data, the like, and combinations thereof.

Suitable physico-chemical data sets should include at least some of: residual soil nutrient levels exemplified by macronutrients and micronutrients, pH, EC (i.e., electroconductivity), soluble salts as a measure of EC, soil texture, mineral composition, moisture, organic matter content, and the like. Exemplary soil macronutrients include nitrogen, phosphorus, potassium, sulfur, calcium and magnesium. Exemplary soil micronutrients include boron, chlorine, cobalt, copper, iron, magnesium, manganese, molybdenum, nickel and zinc.

Reference data sets of agronomic recommendations may include suitable fertilization practices for optimal yields of the selected crop, wherein suitable fertilization practices may include information exemplified by options for fertilizer formulations and recommended rates of application of each type of fertilizer formulation. It is within the scope of the present invention to provide reference data sets of agronomic recommendation for a number of different crops suitable for production in the agricultural field. The reference data sets may also include lists of common plant pests, microbial pests, insect pests and other relevant biological pests of the selected crop, as well as lists of chemical pesticides and biological pesticides registered by the appropriate agencies for use to eradicate the target pests. Other suitable reference data sets are exemplified by historical weather data from previous crop production cycles.

Each set of input data is separately processed, analyzed, summarized, and identified for storage and retrieval in a suitable electronic database as exemplified by enterprise resource planning software-driven databases. The individual processing module components are each provided with one or more suitable algorithms for processing, sorting, analyzing, summarizing and preparing suitable reports for each of the input data sets. Some processing modules are suitably configured for comparing and correlating selected different types of input data sets. Input data sets may also comprise service provider information, user/client information. The related systems of the present invention may be integrated with and cooperate with the methods to enable multiple user/clients to access a service provider's database via online access or alternatively, via a VPN-based (virtual private network) web portal wherein each user's access and interaction with the service provider's database and processing modules, is secure.

An exemplary method and related system 5 for providing variable zone-based crop-specific fertilization prescriptions for a selected agricultural field is shown in Fig. 2. After a farmer selects an agricultural field 10 for which he wishes input prescriptions for selected crops to facilitate their crop selection and production management decisions, suitable high-resolution geo-referenced aerial imagery is obtained to determine and acquire the field's shape, dimensions, and boundaries. The field's boundaries can be saved as geo-referenced (e.g., GPS) shape file or polygon that is accessible by GIS-based programs. The field's topography can be integrated into one or more selected polygons from which a site-specific geo-referenced field shape file 20 is produced. It is optional to incorporate a site-specific topography map into the field shape file 20 if so desired. One of a site-related multispectral satellite imagery, and hyperspectral satellite imagery collected in previous years, is obtained and clipped onto the field shape file 20 to produce a site-specific vegetation sitemap 30. It is suitable if so desired to obtain, process and correlate several site related satellite imagery to produce an averaged satellite imagery to clip onto the field shape file 20. The near-infrared bands and red bands of multispectral imagery are vectored to a vectorized polygon grid, after which a normalized difference vegetation index (NDVI) pertaining to the distribution of ranges of biomass densities within and throughout the field, can be calculated 40. The NDVI values are then classified and grouped into several classes wherein each class has similar ranges of biomass density distribution. The classes are interpolated using suitable geostatistical techniques exemplified by kriging, nearest-neighbor, inverse distance, Delauney triangulation, minimum curvature, polynomial regression, radial basis function, Shepard's method, the like, and combinations thereof, into about 4 to 8 zones that comprise the agricultural field. The NDVI classes may be created by methods of classification exemplified by natural breaks, equal area, equal intervals, the like, and combinations thereof. The zones are then mapped onto one or more field map templates, and the number of acres within each zone is calculated 50. It is suitable to refer to these zones as "soil management zones" or "integrated management zones". It is suitable to use NDVI data from a single growing season to identify and locate the soil management zones comprising the agricultural field. However, it is preferable to combine NDVI data from two or more growing seasons for more precise delineation of the soil management zones within and about the agricultural field. Alternatively, the soil management zones may be more precisely delineated by correlating the NDVI data with one or more of a topographical map, soil moisture distribution throughout the field, crop yield

data using algorithms exemplified by fuzzy k-means clustering and by the minimum-volume embedding algorithm.

After the soil management zones have been delineated for the agricultural field, a pattern of soil sampling suitable numbers of sites within each soil management zone throughout the agricultural field is derived **60**. Soil samples are then collected and analyzed for selected macronutrients and micronutrients, and at least some of soil pH, soil EC, soluble salts, texture, mineral composition and organic matter content **70**. The soil analysis results provide a physico-chemical profile for each of the soil management zones. The physico-chemical profiles are then compared to reference data sets pertaining agronomic fertility inputs for optimal production of a selected crop, and the differences are then reported for each soil management zone **80**. Using information provided by the farmer regarding the list of crops he is considering growing during the upcoming production season **100**, agronomic recommendations for each of the selected crops e.g., **111**, **112**, **113**, are input, and a set of equations **120** then calculates a set of fertilizer application rates (i.e., prescriptions) for selected macronutrients and micronutrients for each of the soil management zones for each of the selected crops **131**, **132**, **133**.

Weather conditions and crop development occurring during a growing season often proceed outside of predictions and calculated projections that were made prior to crop sowing. For example, unusually high ambient temperatures for extended periods of time coupled with ideal precipitation and soil moisture conditions can produce un-anticipated rapid rates of crop growth and development that may result in depletion of soil nutrient levels that were previously adjusted according to prescriptions. Alternatively, excessive precipitation coupled with unusually cool ambient temperatures could result in depletion of the anionic components of applied fertilizers through leaching (e.g., nitrates) or precipitation (e.g., phosphates) that may result in the occurrence of crop nutrient stresses. Accordingly, it is within the scope of the present invention to adapt the method and systems exemplified in Fig. 2 to provide one or more variable zone-based crop-specific inputs prescriptions during the course of a crop production cycle on a selected agricultural field, to augment crop inputs prescriptions provided prior to the commencement of growing season. It is known that different and varying concentrations of macronutrients and micronutrients in soils will cause changes in the reflectance of crops growing in those soils. Such changes in crop reflectance are detectable with hyperspectral imagery. In

addition to acquiring one or more selected satellite imagery during the production of the selected crop in the agricultural field for determination of real-time NDVI indices and NDVI zones across the field, other suitable real-time crop production parameter inputs are exemplified by crop seeding date, crop development stage exemplified by tillering, leaf-stage data and the like, the results of supplementary analyses performed on soil samples collected at one or more selected post-seeding time periods. Inputting data sets comprising hyperspectral information, in combination with other selected crop production parameter data, enables early detection of the potential occurrence and severity of macronutrient and/or micronutrient deficiencies associated with the unusual weather conditions occurring during the early stages of crop production. Accordingly, the processing module then calculates using appropriately adapted algorithms, a set of in-season fertilization prescriptions for each of the soil management zones across the field to ameliorate the potential nutrient deficiencies thereby enabling mid-season optimization of crop production.

Several pest events invariably occur during the course of a crop production cycle. Various types of pests exemplified by weeds, insects and microbial diseases are commonly associated with certain geographies, agronomic practices and/or crop types. The severity of damage caused to the crop can be ameliorated by prophylactic applications of certain chemical pesticides, alternatively by early detection of pest appearance and immediate application of one or more suitable chemical or biological pesticides. Quite often, the severity of pest infestation is exacerbated by weather conditions. Accordingly, certain aspects of the present invention relate to use and analyses of data collected by several different pest monitoring and detection systems exemplified by crop scouting and satellite images, for early detection of localized pest appearance in one or more soil management zones comprising the agricultural field. An exemplary method and related system **200** for providing pest management prescriptions during a crop production cycle is shown in Fig. 3. In response to a farmer's request for one or more pest management prescriptions for a selected field for which a geo-referenced field shape file template **20** has been previously produced, real-time spectral imagery is obtained for the crop being produced to enable preparation for a real-time vegetation sitemap **210**. The real-time NDVI index **220** is determined across the vegetation site map, after which the related biomass distribution values are calculated, then classified and grouped into about 4 to 8 soil management zones that comprise the agricultural field **230**. Collected pest scouting data pertaining to the

appearance of pest types and their distribution **240** across the NDVI zones delineating the agricultural field are input. Historical weather data from previous production cycles **250** and current weather forecast projections **260** are input. Also input are suitable agronomic recommendations pertaining to recommended pest control products and management practices
5 for each of the identified pests **270**. The processing module **280** processes, calculates and correlates the pest scouting data sets with the NDVI zones across the agricultural field, the historical weather data, and with the current weather forecasts, after which the periods of highest risk for development of significant diseases, insect and weed pests are calculated, projected and reported. Concomitantly, the processing module **280** correlates the disease risk projections to
10 reference data sets of chemical pesticides and biological pesticides and to the agronomic recommendations for pest management and provides prescription options ,e.g., **291, 292, 293**, for selection of suitable pest control products, related recommended application rates for each of the soil management zones, and timing of applications.

Weed control products represent a significant cost for agricultural producers. Current
15 management strategies to control these costs are focused on booking volume quantities of selected herbicides in advance of the growing season in anticipation that certain weed pests will appear and will need to be controlled. It is within the scope of the present invention to adapt the exemplary method and system shown in Fig. 3 for providing weed control prescriptions pertaining to one or more selected crops, type of crop rotation employed on the agricultural
20 field, historical data pertaining to crop production and yield during the previous year and related data sets pertaining to weed infestation and herbicide applications, historical weed infestation problems and herbicide usage, and to correlate the processed data with probability analyses of potential weed infestation spectra with the selected crop during the planned growing season, with reference data pertaining to forecast weather conditions throughout the growing seasons, and to
25 lists of suitable herbicides. The output data sets will provide recommendations for one or two suitable herbicides, forecasts of likely required application rates on a soil management zone basis and related timing of application, and the volumes of each herbicide required.

It is within the scope of the present invention to adapt the methods and systems of the present invention to input one or more set(s) of historical annual crop production records for a
30 selected agricultural field, to enable refinement of crop prescriptions for an upcoming production

cycle. Each annual historical record set could include the type of crop grown, sowing and harvesting dates, fertility and pest management product inputs before and during crop production, soil physico-chemical data produced from soil samples collected throughout the field prior to the crop production, weather data, survey data noting crop health, vigor, and pest occurrence during the production period, crop yields, and the like. It is a common agricultural practice to rotate the type of crop grown on an agricultural field from year to year. Accordingly, providing the methods and systems of the present invention with a plurality of historical annual record inputs for an agricultural field whereon multiple crops have been produced over several production cycles, will enable averaging of historical production data for each crop. Such historical annual record inputs will facilitate the preparation of prescriptions for several crop options for an upcoming production cycle and will enable comparison of projected production costs for each crop option, and related projections of returns on investment. Accordingly, incorporation of historical annual production records into the methods and systems of the present invention can be used to facilitate crop selection and production planning for an upcoming production cycle.

The methods and systems therefor of the present invention for providing variable zone-based crop inputs prescriptions for optimized production of selected crops in selected agricultural fields wherein each field comprises a plurality of soil management zones, are described in more detail in the following examples which are intended to be exemplary of the invention and are not intended to be limiting.

Example 1:

The following example relates to the exemplary method shown in Fig. 2 for providing crop-specific zone-variable fertilization prescriptions for a selected agricultural field. Fig. 4 shows a high-resolution aerial imagery 300 of three agricultural fields in south eastern Alberta having the legal land description of N 28 28 24 W4; 08. The middle field 310 with perimeter boundaries illustrated with the dashed line 30, was chosen as the subject agricultural field. The middle field 320 encompassed 158.97 acres (rounded up to 159 ac for this example). Subsequently, a shape file template was prepared for the middle field 20. A service provider would purchase such suitable imagery when a user/client identifies such fields for prescription of

crop inputs. Fig. 5 shows a spectral satellite imagery clipped to the middle field template, and an analysis and classification were performed on the related NDVI values pertaining to biomass density distributions, resulting in the identification of 7 soil management zones. Fig. 6 shows the distribution and locations of individual soil sampling sites throughout the soil management zones and about the agricultural field. Based on the soil testing results, the recommendations for application of urea fertilizer to the field ranged from 1 (soil management zone 1) to 128 lbs/ac (soil management zone 7) with a total urea fertilizer recommendation of 13,693.4 lbs (Table 1).

Table 1:

Soil management zone	Number of acres	Recommended application rate for urea fertilizer (lb/ac)	Total fertilizer applied (lb)
1	25.0	0	0
2	1.4	0	0
3	10.8	49	556.8
4	18.3	91	1,619.8
5	8.9	98	5,752.6
6	59.8	102	887.4
7	39.2	128	4,876.8
Total	159		13,693.4

10 Example 2:

Fig. 7 shows a high-resolution aerial imagery of another agricultural fields in south eastern Alberta having the legal land description of SW 34 28 24 W4; 08, with perimeter boundaries illustrated with the dashed line. This field encompassed 157.05 acres. Subsequently, a polygon outlining the field boundary was prepared for the middle field 20. A service provider would purchase such suitable imagery when a user/client identifies such fields for prescription of crop inputs. Fig. 8 shows a NDVI map created from a multispectral image and clipped to the polygon outlining the middle field boundary, and an analysis and classification were performed

on the related NDVI values pertaining to biomass density distributions, resulting in the identification of 7 soil management zones. Fig. 9 shows the distribution and locations of individual soil sampling sites throughout the soil management zones and about the agricultural field. Based on the soil testing results, the recommendations for application of urea fertilizer to the field ranged from 54 lbs/ac (soil management zone 1) to 100 lbs/ac (soil management zone 7) with a total urea fertilizer recommendation of 12,598.8 lbs (Table 1).

Table 2:

Soil management zone	Number of acres	Recommended application rate for urea fertilizer (lb/ac)	Total fertilizer applied (lb)
1	0.5	54	27.0
2	1.7	54	91.8
3	4.9	72	352.8
4	19.9	72	1,432.8
5	38.3	76	2,910.8
6	58.6	76	4,453.6
7	33.3	100	3,330.0
Total	157.1		12,598.8

Example 3:

Following is a prophetic example illustrating an exemplary embodiment of the present invention relating to a client alert method and system for a prescribed application of a pest control product according to previously submitted prescription request. The assumption is that a client is producing a barley crop on a selected field that was previously mapped, analysed, and characterized, and wishes to apply a herbicide product for prophylactic control of weed pests. The preferred herbicide product may have the following use instructions/restrictions: the product should not be applied if the weather forecasts that within the 12-hour period after application, the ambient temperature may drop below +5° C or go above +32° C, and if the soil moisture is below a specified level. Additionally, the herbicide product should be applied to barley between

the 1-leaf–5-leaf stages and with 2 tillers. Based on data inputs that would include at least sowing date, collected post-seeding growing-degree data, barley leaf-stage data, barley tiller data, zone-based soil moisture data, ‘real-time’ NDVI data, and current weather forecast information, the method and systems are configured to send one or more daily wireless alerts to the client indicating whether the herbicide should or should not be applied. If the real-time data processing and correlations result in prescribing several days of ‘do not apply’ recommendations, then it is suitable to further adapt the method and systems to select an alternative and more appropriate herbicide product for application.

While this invention has been described with respect to the exemplary embodiments, those skilled in these arts will understand how to modify and adapt the methods and systems providing variable zone-based crop inputs prescriptions for optimized production of selected crops. For example, it is suitable to provide input data sets pertaining to real-time futures pricing for the crop commodity being grown on the selected agricultural field and to adapt the processing module for processing and correlating the futures pricing with the pre-season and in-season crop inputs prescriptions, thereby enabling deliveries of real-time profit/loss projection outputs for facilitating in-season crop inputs management decision-making.

CLAIMS

What is claimed is:

1. A method of providing a variable zone-based crop inputs prescription for an agricultural field, the method comprising the steps of:

establishing a geo-referenced spatial boundary around the periphery of the field, said spatial boundary defining a geo-referenced production area;

calculating from a spectral satellite imagery encompassing the field, a normalized difference vegetation index (NDVI) distribution within said geo-referenced production area, said NDVI distribution correlated to a plurality of biomass density ranges distributed within and about said geo-referenced production area;

delineating the geo-referenced production area into a set of zones wherein each zone corresponds with a biomass density range from said NDVI distribution;

collecting a plurality of soil samples from within and about each zone;

analyzing each of the plurality of soil samples and producing therefrom a set of sampled physico-chemical data;

comparing the set of sampled physico-chemical data with a reference physico-chemical data set from an agronomic recommendation for optimal production of a selected first agricultural crop, calculating a first inputs prescription for optimal production of said first agricultural crop in said production area, said inputs prescription comprising a set of calculated input recommendations correlated to the zones delineating the production area, wherein each input recommendation is directed to a zone and comprises the differences between the reference physico-chemical data set from the agronomic recommendation and the set of sampled physico-chemical data.

2. A method according to claim 1, wherein said geo-referenced spatial boundary is derived from at least one of high-resolution aerial imagery encompassing the field and spectral satellite imagery encompassing the field.

3. A method according to claim 1, wherein the spectral satellite imagery is selected from the group consisting of panchromatic satellite imagery, multispectral satellite imagery and hyperspectral satellite imagery.
4. A method according to claim 1, wherein the spectral satellite imagery is an averaged composite spectral satellite imagery produced from a plurality of spectral satellite imagery having about the same geographic information system coordinates.
5. A method according to claim 4, wherein each imagery comprising the plurality of spectral satellite imagery is captured at a selected time period during a crop production cycle in said field.
6. A method according to claim 4, wherein each imagery comprising the plurality of spectral satellite imagery is captured at about selected 12-month intervals.
7. A method according to claim 1, wherein said agricultural field is an un-tilled field.
8. A method according to claim 1, wherein said agricultural field is a tilled field.
9. A method according to claim 1, wherein the variable crop inputs prescription comprises at least one of a set of nutrient inputs and a set of pest management inputs.
10. A method according to claim 9, wherein said set of nutrient inputs comprises one or more macronutrients.
11. A method according to claim 9, wherein said set of nutrients comprises at least one macronutrient selected from a group consisting of nitrogen, phosphorus, potassium and sulfur.
12. A method according to claim 9, wherein said set of nutrient inputs comprises one or more micronutrients.

13. A method according to claim 9, wherein said set of nutrient inputs comprises at least one macronutrient and at least one micronutrient.

14. A method according to claim 9, wherein said set of nutrient inputs comprises organic nutrients.

15. A method according to claim 9, wherein said set of pest management inputs comprises one or more chemical pest management products.

16. A method according to claim 9, wherein said set of pest management inputs comprises one or more biological pest management products and/or materials and/or practices.

17. A method according to claim 1, wherein said method additionally comprises steps of:

collecting at least one set of crop development data points during production of a selected crop in said geo-referenced production area wherein each data point comprising said set of crop development data points corresponds to a soil management zone delineating said geo-referenced production area;

comparing said set of crop development data points to said set of agronomic recommendations for selected physico-chemical criteria useful for optimal production of a selected agricultural crop;

producing therefrom said comparison a first adjusted set of selected physico-chemical criteria for optimal production of said selected agricultural crop in said geo-referenced production area wherein the adjusted set of selected physico-chemical criteria comprises a first discrete adjusted selected physico-chemical criteria data set for each zone delineating said geo-referenced production area; and

calculating an inputs prescription for optimal production of said agricultural crop in said geo-referenced production area, said inputs prescription comprising a set of input recommendations correlated to the zones delineating the geo-referenced production area wherein each input recommendation is directed to a zone and comprises the differences between the adjusted selected physico-chemical criteria data set for said zone and the set of physico-chemical data produced for the plurality of soil samples from said zone.

18. A method according to claim 17, wherein each data point comprising said set of crop development data points is selected from the group consisting of leaf-stage data, tillering data, leaf area data, plant biomass data, and crop yield data.

19. A method according to claim 17, wherein each data point comprising said set of crop development data points is one of a total of a plurality of crop development data collected about each soil management zone delineating said production area and an average of the plurality of crop development data collected about said zone.

20. A method according to claim 17, wherein pluralities of sets of crop development data points are compared to said set of agronomic recommendations for selected physico-chemical criteria useful for optimal production of a selected agricultural crop, wherein each plurality of said sets of crop development data points is collected during a separate crop production cycle and each data point corresponds to a zone delineating said production area.

21. A method according to claim 20, wherein each plurality of said sets of crop yield data points is collected at about the same stage of crop development.

22. A method according to claim 20, wherein said data points corresponding to a zone delineating said production, are averaged.

23. A method according to claim 17, wherein said method additionally comprises steps of:

collecting a first set of soil analytic data throughout a course of crop production of said first agricultural crop in said production area wherein said set of soil analytic data comprises a plurality of subsets of soil analytic data collected at selected spaced-apart time intervals from about the time of crop planting to about the time of crop harvest;

collecting a first set of weather data throughout the course of crop production of said first agricultural crop in said production area wherein said set of weather data comprises a plurality of subsets of weather data collected at selected spaced-apart time intervals from about the time of crop planting to about the time of crop harvest;

analyzing said first sets of soil analytic data and weather data, and determining therefrom a first plurality of soil analytic patterns and weather patterns throughout said course of crop production;

correlating said first plurality of soil analytic patterns and weather patterns with the set of crop yield data points;

producing therefrom said correlation, a second adjusted set of selected physico-chemical criteria for optimal production of said selected agricultural crop in said production area wherein the second adjusted set of selected physico-chemical criteria comprises a second discrete physico-chemical criteria data set for each zone, said second discrete physico-chemical criteria data set correlated to the first plurality of soil analytic patterns and weather patterns; and

calculating an inputs prescription for optimal production of said agricultural crop in said production area correlated to the plurality of soil analytic patterns and weather patterns, said inputs prescription comprising a set of input recommendations correlated to the zones delineating the production area wherein each input recommendation is directed to a zone and comprises the differences between the second discrete physico-chemical criteria data set for said zone and the set of physico-chemical data produced for the plurality of soil samples from said zone.

24. A method according to claim 23, wherein the set of soil analytic data comprises one or more of soil temperature, soil moisture, soil nutrient composition, and combinations thereof.

25. A method according to claim 23, wherein the set of weather patterns comprises one or more of precipitation, air temperature, air humidity, solar irradiation intensity, wind velocity, and combinations thereof.

26. A method according to claim 23, wherein said method additionally comprises steps of:

collecting at least a second set of soil analytic data throughout at least a second course of crop production of said first agricultural crop in said production area wherein said second set of soil analytic data comprises a plurality of subsets of soil analytic data collected at selected spaced-apart time intervals from about the second time of crop planting to about the second time of crop harvest;

collecting at least a second set of weather data throughout at least a second course of crop production of said first agricultural crop in said production area wherein said second set of weather data comprises a plurality of subsets of weather data collected at selected spaced-apart time intervals from about the second time of crop planting to about the second time of crop harvest;

analyzing said second sets of soil analytic data and weather data, and determining therefrom a second plurality of soil analytic patterns and weather patterns throughout said second course of crop production;

correlating said second plurality of soil analytic patterns and weather patterns with a second set of crop yield data points collected during the second course of crop production;

producing therefrom said correlation, a third adjusted set of selected physico-chemical criteria for optimal production of said selected agricultural crop in said production area wherein the third adjusted set of selected physico-chemical criteria comprises a third discrete physico-chemical criteria data set for each zone, said third discrete physico-chemical criteria data set correlated to the second plurality of environmental criteria patterns; and

calculating an inputs prescription for optimal production of said agricultural crop in said production area correlated to the second plurality of soil analytic patterns and weather patterns, said inputs prescription comprising a set of input recommendations correlated to the zones delineating the production area wherein each input recommendation is directed to a zone and comprises the differences between the third discrete physico-chemical criteria data set for said zone and the set of physico-chemical data produced for the plurality of soil samples from said zone.

27. A method according to claim 1, wherein said set of suitable agronomic recommendations for selected physico-chemical criteria useful for optimal production of said selected agricultural crop comprises at least one subset of suitable agronomic recommendations for optimal production of said crop during a period of one or more environmental stresses.

28. A method according to claim 27, wherein said one or more environmental stresses is selected from the group consisting of drought stress, excessive moisture stress, heat stress, low-temperature stress, soil salinity stress, solar irradiation stress, and pests.

29. A method according to claim 27, wherein said one or more environmental stresses are pests selected from the group of plant pests, microbial pests, viral pests and insect pests.

30. A method according to claim 1, additionally comprising calculating at least a second inputs prescription for optimal production of at least a second selected agricultural crop in said production area, wherein said second inputs prescription is calculated in reference to a second set of suitable agronomic recommendations for selected physico-chemical criteria useful for optimal production of said second selected agricultural crop, said inputs prescription comprising a set of calculated input recommendations correlated to the zones delineating the production area wherein each input recommendation is directed to a zone and comprises the differences between the second set of agronomic recommendations for selected physico-chemical criteria for optimal production of said second selected agricultural crop and the set of physico-chemical data produced for the plurality of soil samples from said zone.

31. A system for providing a variable crop inputs prescription for an agricultural field, the system comprising:

a component for receiving and/or acquiring inputs from at least one of high-resolution aerial imagery encompassing the field and topographical mapping within and about the field, detecting a geo-referenced spatial boundary about the field and producing therefrom at least one of a geo-referenced a map file and a polygon defining a geo-referenced production area within said geo-referenced spatial boundary;

a component for receiving and/or acquiring inputs from at least one spectral satellite imagery relating to the field, and clipping said spectral satellite imagery to said geo-referenced mapshape template thereby producing therefrom a vegetation map defining said geo-referenced production area;

at least one component for: (a) calculating from said vegetation map a NDVI index within said geo-referenced production area, said NDVI index comprising a plurality of biomass

density ranges distributed within and about the geo-referenced production area, and (b) delineating said geo-referenced production area into a set of soil management zones wherein each soil management zone correlates with a biomass density range from said NDVI index;

a component for calculating a suitable number of soil sampling sites within and about the set of soil management zones, and mapping said soil sampling sites onto a geo-referenced mapshape template for reference thereto;

a component for at least one of receiving, processing, analysing, storing and reporting a set of physico-chemical data produced by analyses of a set of soil samples collected from said field according to said geo-referenced soil-sampling mapshape template, and delineating the set of analysed soil physico-chemical data into subsets wherein each subset corresponds to a soil management zone;

a component for receiving and/or acquiring inputs comprising agronomic production recommendations for at least one crop, said recommendations selected from the group consisting of fertility recommendations, pest control recommendations, pest management recommendations, crop production recommendations, and combinations thereof;

a component for comparing and/or correlating at least the subset of soil physico-chemical data for each soil management zone to said agronomic production recommendations, wherein said comparison and/or correlation includes at least one of calculating, analyzing, summarizing, storing and reporting differences therebetween the subset of soil physico-chemical data and said agronomic production recommendations; and

a component for producing from at least the compared and/or correlated subset of soil physico-chemical data and agronomic production recommendations, a variable crop inputs prescription for the geo-referenced production area pertaining to production of the at least one crop, wherein the crop inputs prescription comprises a crop inputs recommendation for each of said soil management zones.

32. A system according to claim 31, wherein the spectral satellite imagery is selected from the group consisting of panchromatic satellite imagery, multispectral satellite imagery, and hyperspectral satellite imagery.

33. A system according to claim 31, wherein the spectral satellite imagery is an averaged composite spectral satellite imagery produced from a plurality of spectral satellite imagery having about the same GIS coordinates.

34. A system according to claim 31, wherein the agricultural field is one of an un-tilled field and a tilled field.

35. A system according to claim 31, additionally comprising a component for receiving and/or acquiring inputs comprising at least one set of crop development data points collected during a previous production of the crop in said geo-referenced production area wherein each data point comprising said set of crop development data points corresponds to a soil management zone delineating said geo-referenced production area, and for processing said set of crop development data points to produce a processed data set that is suitable for comparing and/or correlating with at least one of the subset of soil physico-chemical data and the agronomic production recommendations.

36. A system according to claim 35, where each data point comprising said set of crop development data points is one of a sum of a plurality of crop development data collected about each soil management zone delineating said production area and an average of the plurality of crop development data collected about said soil management zone.

37. A system according to claim 31, additionally comprising a component for receiving and/or acquiring inputs comprising historical weather data from at least one previous production cycle, wherein said historical weather data is processed and made suitable for comparing and/or correlating with at least one of the subset of soil physico-chemical data and the agronomic production recommendations.

38. A system according to claim 31, additionally comprising a component for receiving and/or acquiring inputs comprising at least one set of environmental criteria data points collected during a course of crop production of said crop in said geo-referenced production area wherein said set comprises a plurality of subsets of environmental criteria data points collected at selected spaced-apart time intervals from about the time of crop planting to about the time of crop

harvest, and for processing said set of environmental criteria data points to produce a processed data set that is suitable for comparing and/or correlating with at least one of the subset of soil physico-chemical data and the agronomic production recommendations.

39. A system according to claim 38, where in the at least one set of environmental criteria data points consists of one or more of soil temperature, soil moisture, precipitation, air temperature, air humidity, solar irradiation intensity, wind velocity, and combinations thereof.

40. A system according to claim 31, additionally comprising a component for receiving and/or acquiring input data sets collected during a crop production cycle wherein said input data sets comprise one or more of weather data sets, environmental criteria data sets, crop development data sets, pest scouting and/or pest monitoring data sets, and combinations thereof, and for processing said input data sets to produce processed data sets that are suitable for comparing and/or correlating with at least one of the subset of soil physico-chemical data and the agronomic production recommendations.

41. A system according to claim 31, additionally comprising a component for wireless transmission of said variable crop inputs prescription to a client's wireless transmission receiver.

42. A computer readable memory having recorded thereon statements and instructions for execution by a computer to provide a variable zone-based crop inputs prescription for an agricultural field, said statements and instructions comprising:

code means for producing at least one of one of high-resolution aerial imagery encompassing the field and topographical mapping within and about the field, at least one of a geo-referenced map file and a polygon defining a geo-referenced spatial boundary around the periphery of the field, said spatial boundary defining a geo-referenced production area;

code means to clip a selected suitable spectral satellite imagery to the geo-referenced mapshape template thereby producing a vegetation map defining said geo-referenced production area;

code means to calculate from spectral satellite imagery clipped to the geo-referenced mapshape template, a NDVI distribution within and about said geo-referenced production area,

said NDVI distribution correlated to a plurality of biomass density ranges distributed within and about the geo-referenced production area;

code means to delineate the geo-referenced production area into a set of soil management zones wherein each soil management zone corresponds with a biomass density range from said NDVI distribution;

code means to map a series of soil sampling sites onto the geo-referenced mapshape template;

code means to receive, process, categorize, summarize and store agronomic recommendations for production of at least one selected crop;

code means to at least one of process, analyse, summarize and store physico-chemical data derived from soil sample analyses;

code means to calculate site-specific measures of soil nutrients for each soil management zone from the soil sample physic-chemical data;

code means to, for each eco-zone, subtract its site-specific ~~measure~~ measures of soil nutrients from the agronomic recommendations, thereby producing a fertilization prescription for optimal production of the selected crop in said soil management zone; and

code means to produce a variable zone-based crop inputs prescription for production of the at least one selected crop in the field wherein the prescription comprises a fertilization prescription for each of said soil management zones comprising geo-referenced production area.

43. A computer readable memory according to claim 42, additionally comprising code means to cause the computer to receive and store historical weather data, and to further process and correlate said historical weather data with said calculations of site-specific measures of soil nutrients for each eco-zone, thereby producing historical weather-data-adjusted site-specific measures of soil nutrients for each eco-zone for subtraction from the agronomic recommendations, thereby enabling production of a historical-weather-adjusted fertilization prescription for optimal production of the selected crop in each soil management zone.

44. A computer readable memory according to claim 42, additionally comprising code means to cause the computer to receive and store at least one set of historical crop development data points collected during a previous production of the crop in said geo-referenced production area wherein each data point comprising said set of crop development data points corresponds to a soil management zone delineating said geo-referenced production area, and to further process and correlate said historical data with said calculations of site-specific measures of soil nutrients for each eco-zone, thereby producing historical crop development-adjusted site-specific measures of soil nutrients for each soil management zone for subtraction from the agronomic recommendations, thereby enabling production of a historical crop-development-adjusted fertilization prescription for optimal production of the selected crop in each soil management zone.

45. A computer readable memory according to claim 42, additionally comprising code means to cause the computer to receive and store at least one set of historical environmental criteria data collected during a previous production of the crop in said geo-referenced production area wherein each data comprising said set of crop development data corresponds to a zone delineating said geo-referenced production area, and to further process and correlate said historical environmental criteria data with said calculations of site-specific measures of soil nutrients for each eco-zone, thereby producing historical environmental criteria-adjusted site-specific measures of soil nutrients for each eco-zone for subtraction from the agronomic recommendations, thereby enabling production of a historical environmental-criteria-adjusted fertilization prescription for optimal production of the selected crop in each soil management zone.

46. A computer readable memory according to claim 42, additionally comprising code means to cause the computer to:

receive, process, analyze, summarize and store at least one set of current data collected during post-prescription production of the crop in said geo-referenced production area wherein said set of data corresponds to an soil management zone delineating said geo-referenced production area;

compare said set of current data to said set of agronomic recommendations for selected physico-chemical criteria useful for optimal production of a selected agricultural crop;

produce therefrom said comparison an first adjusted set of selected physico-chemical criteria for optimal production of said selected agricultural crop in said geo-referenced production area wherein the adjusted set of selected physico-chemical criteria comprises a first discrete adjusted selected physico-chemical criteria data set for each soil management zone delineating said geo-referenced production area; and

calculating an inputs prescription for optimal production of said agricultural crop in said geo-referenced production area, said inputs prescription comprising a set of input recommendations correlated to the zones delineating the geo-referenced production area wherein each input recommendation is directed to a zone and comprises the differences between the adjusted selected physico-chemical criteria data set for said zone and the set of physico-chemical data produced for the plurality of soil samples from said zone.

47. A computer readable memory according to claim 42, additionally comprising code means to select the current data a group consisting of crop production data, weather data, environmental criteria data, pest scouting and/or pest forecasting data, and combinations thereof.

48. A computer readable memory according to claim 47, additionally comprising code means to select the crop production data a group consisting of leaf-stage data, tillering data, leaf area data, plant biomass data, and crop yield data, and combinations thereof.

49. A computer readable memory according to claim 47, additionally comprising code means to select the weather data from a group consisting of precipitation data, daily high and low ambient temperature data, and combinations thereof.

50. A computer readable memory according to claim 47, additionally comprising code means to select the environmental criteria data from a group consisting of soil temperature, soil moisture, air humidity, solar irradiation intensity, wind velocity, growing-degree data, and combinations thereof.

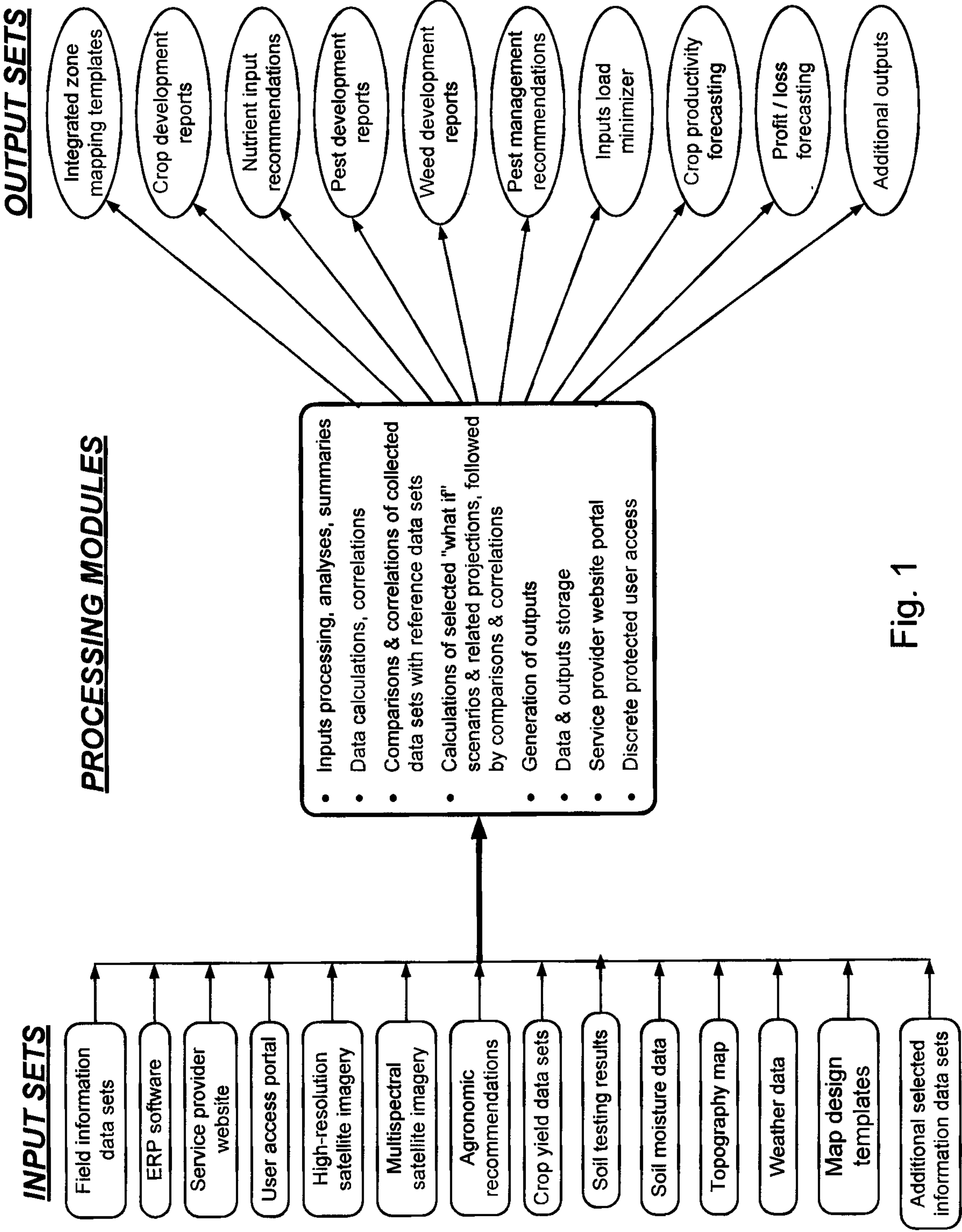


Fig. 1

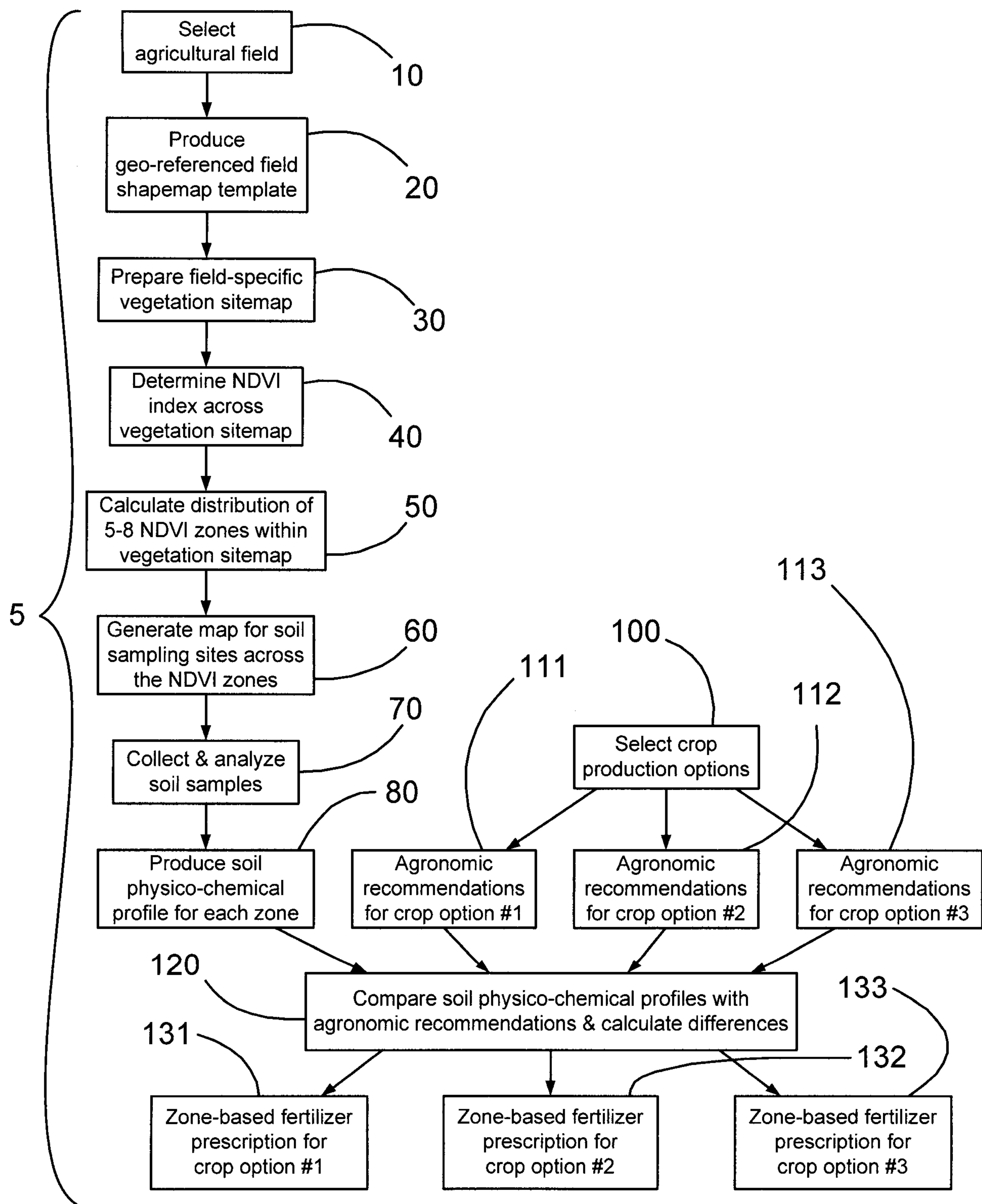


Fig. 2

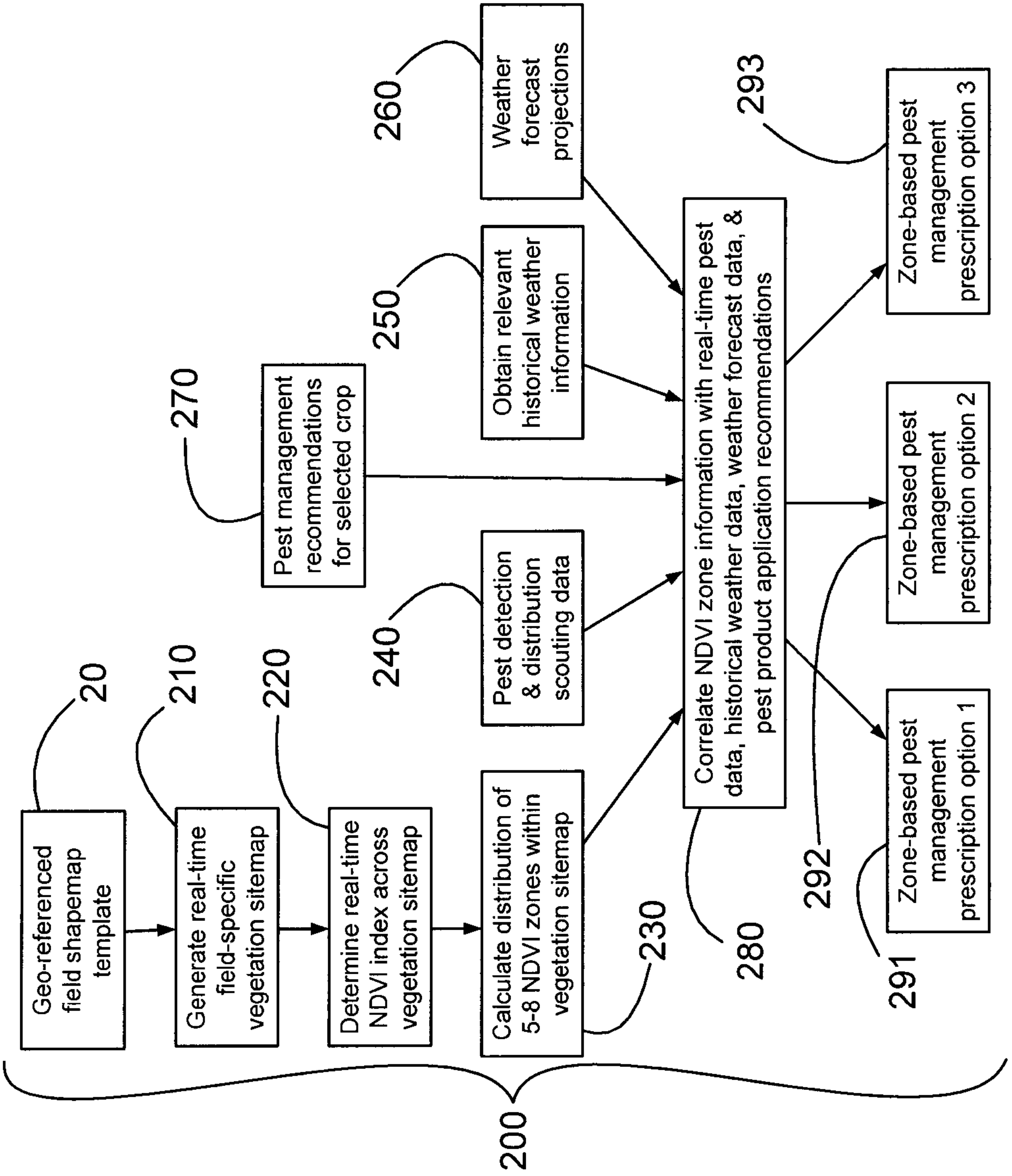


Fig. 3

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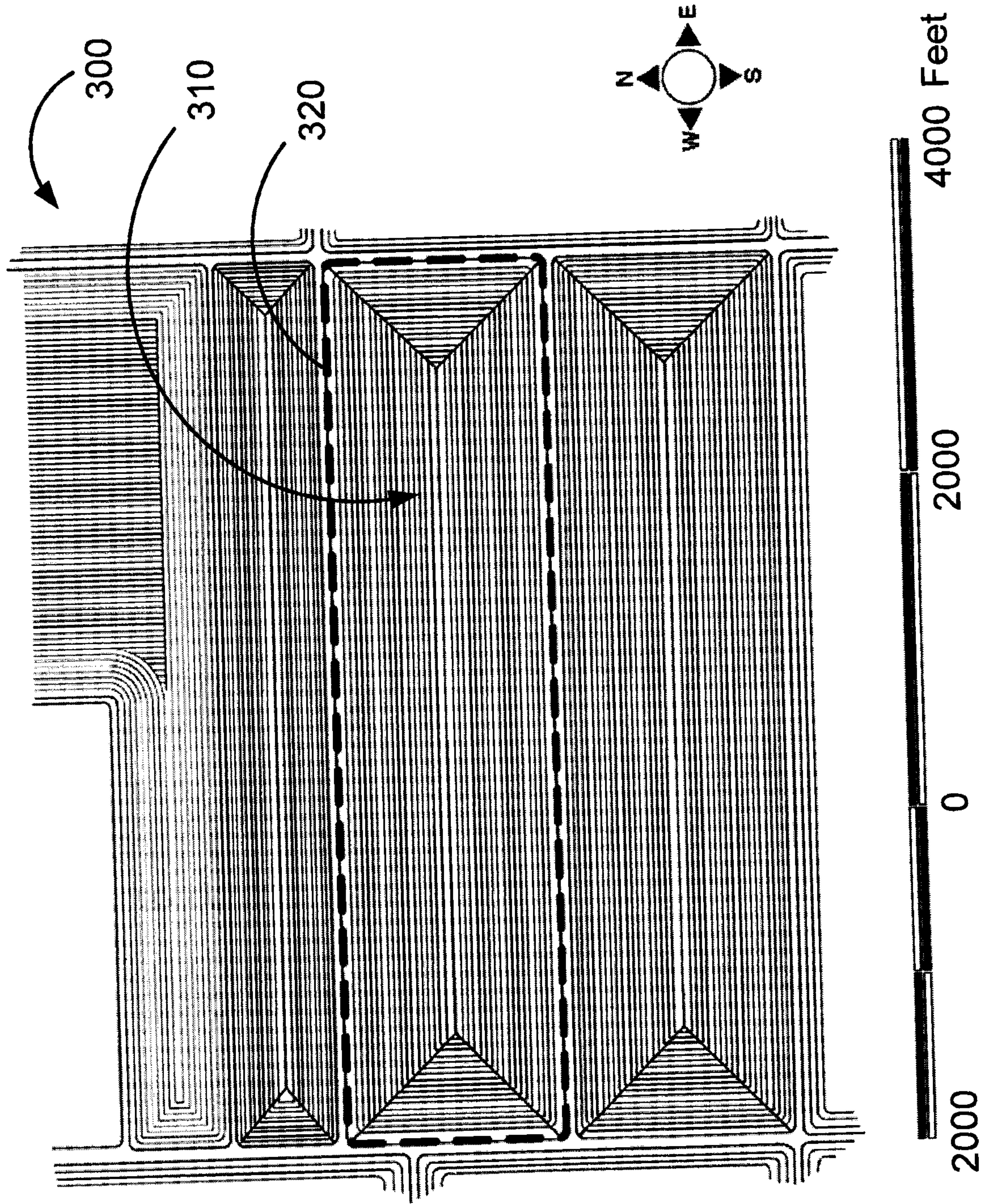


Fig. 4

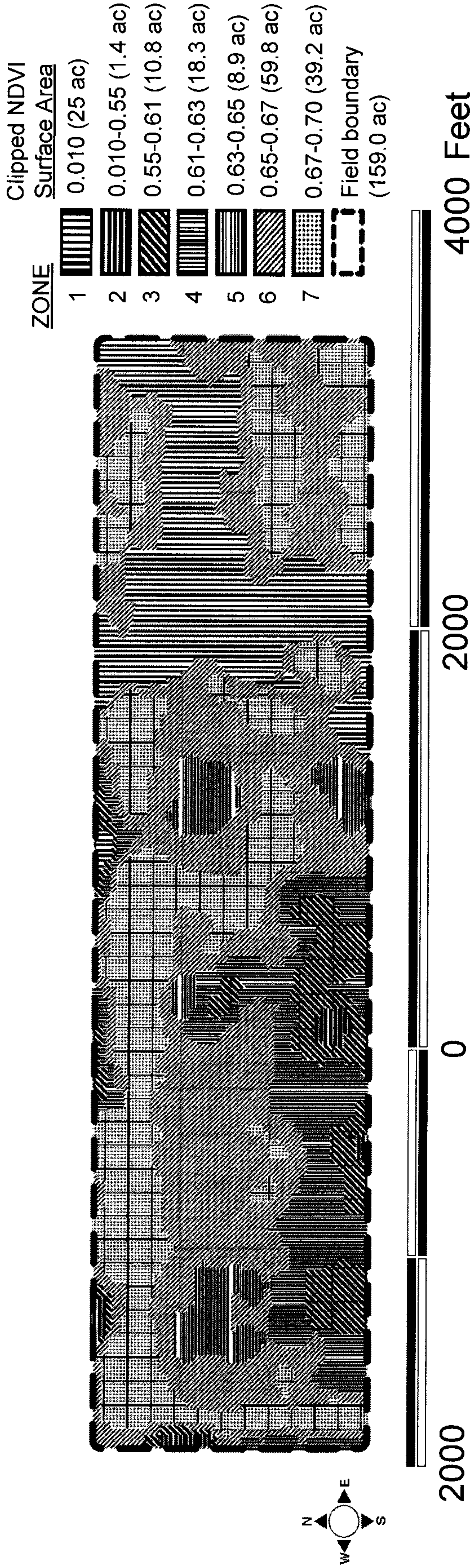


Fig. 5

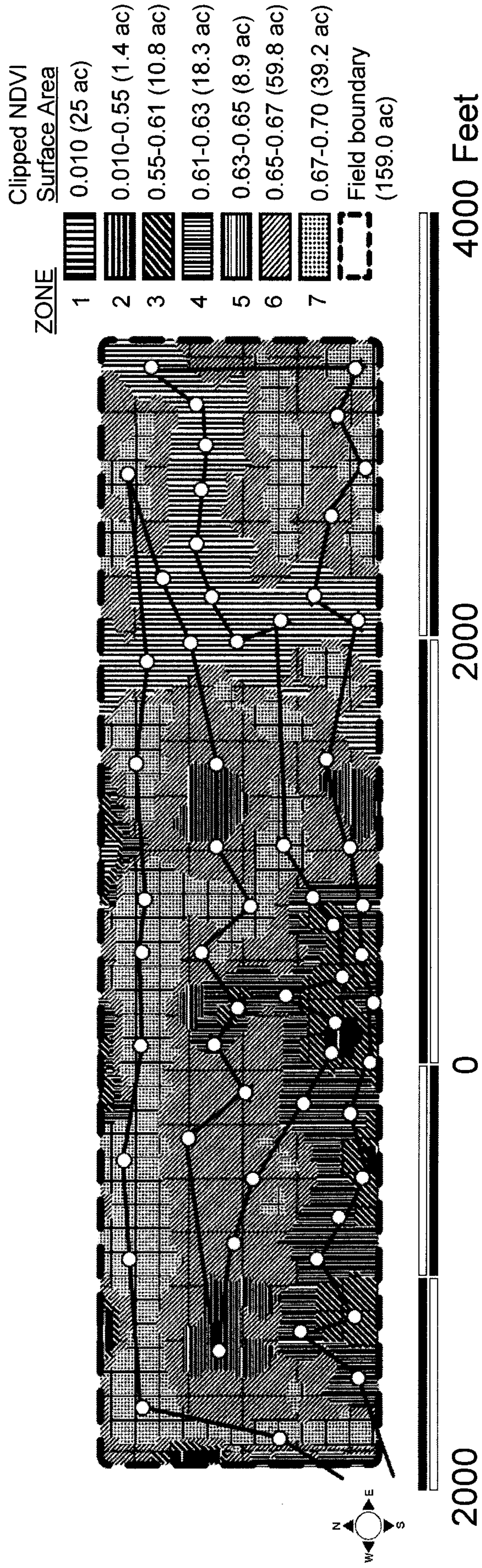


Fig. 6

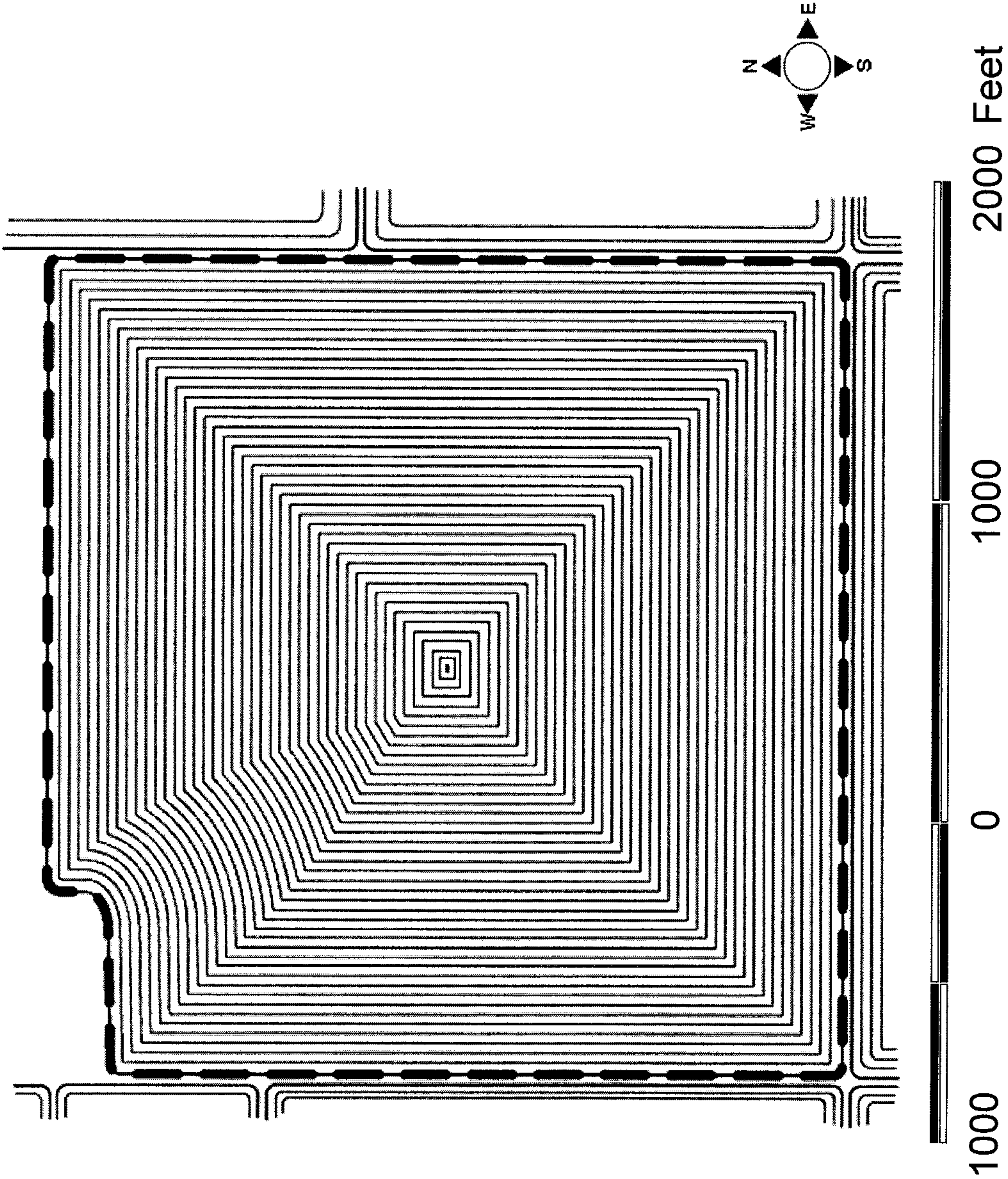


Fig. 7

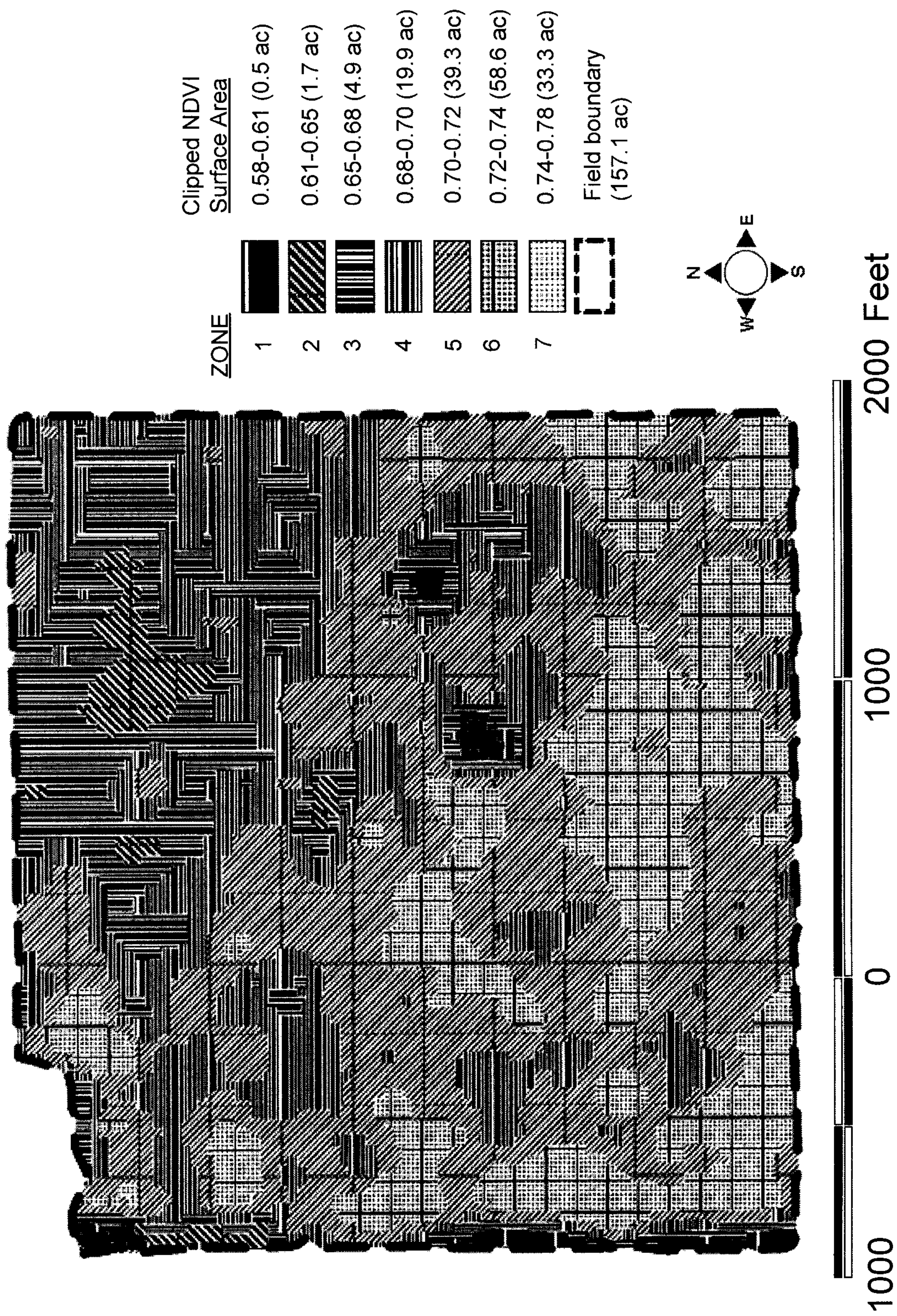


Fig. 8

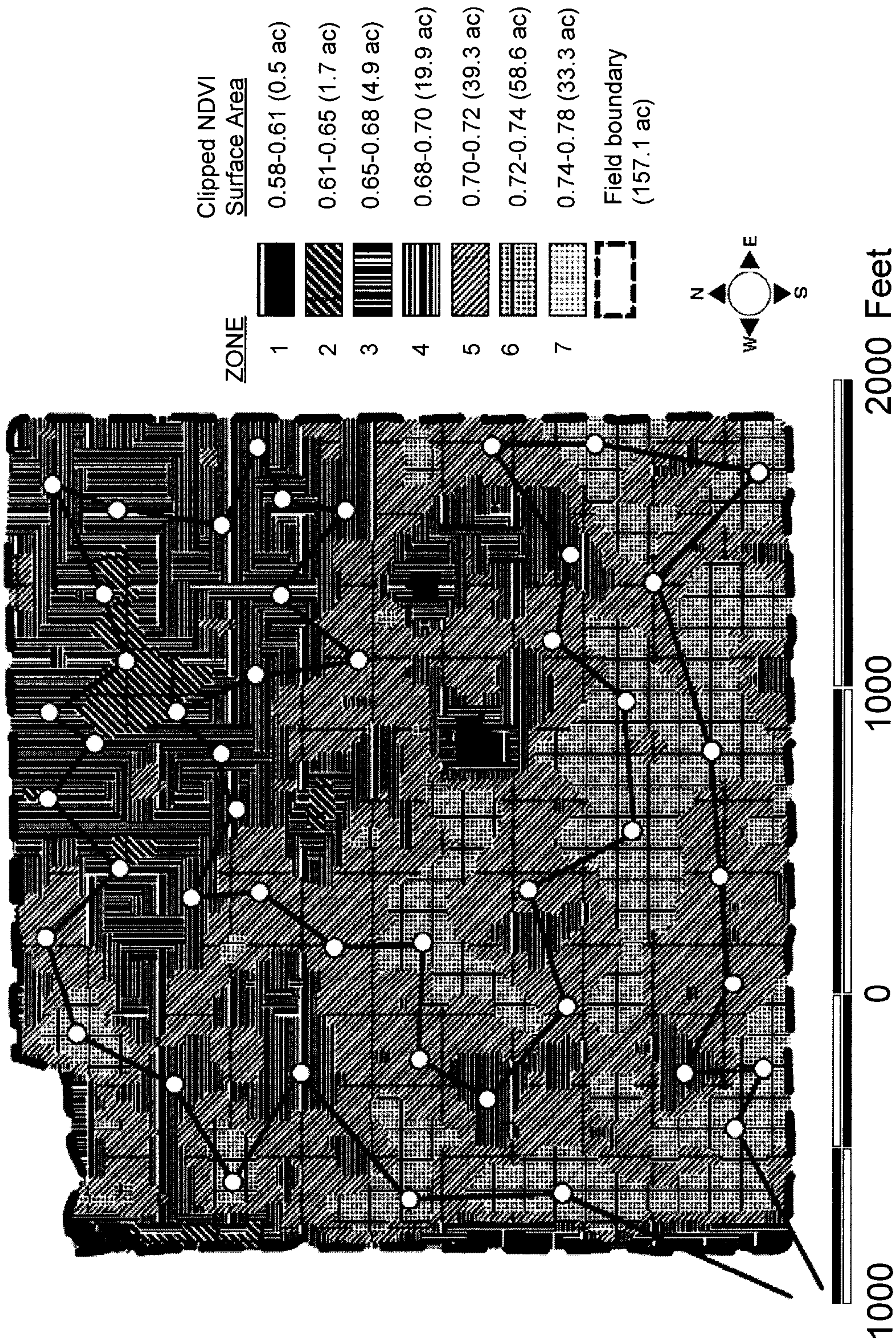
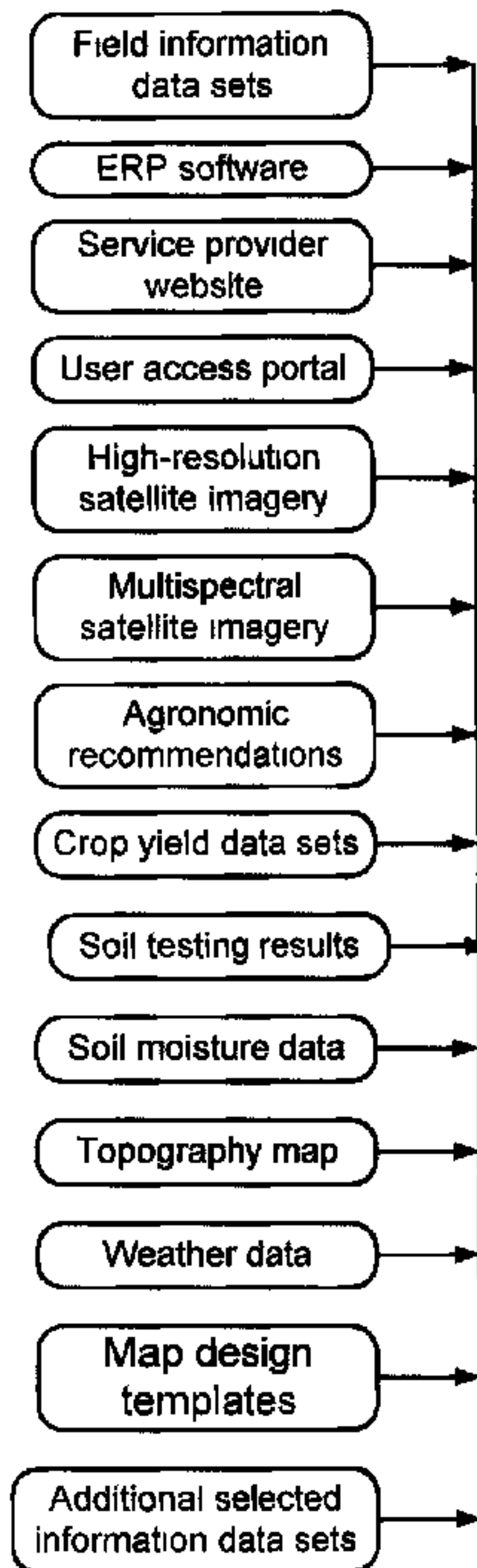


Fig. 9

INPUT SETS



PROCESSING MODULES

- Inputs processing, analyses, summaries
- Data calculations, correlations
- Comparisons & correlations of collected data sets with reference data sets
- Calculations of selected "what if" scenarios & related projections, followed by comparisons & correlations
- Generation of outputs
- Data & outputs storage
- Service provider website portal
- Discrete protected user access

OUTPUT SETS

