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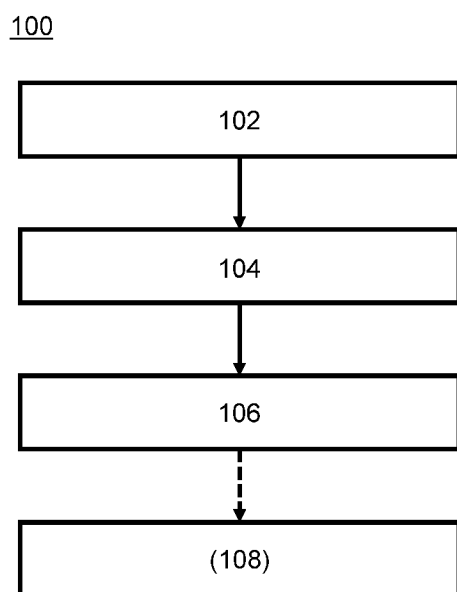
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(54) Title: COMPUTER-IMPLEMENTED METHOD FOR DETERMINING A TREATMENT SCHEDULE BASED ON A SOIL-RELATED SUSTAINABILITY SCORE AS TECHNICAL INDICATOR FOR CARBON FARMING POTENTIAL OF AN AGRICULTURAL FIELD OR A SUB-FIELD ZONE

Fig. 1



(57) Abstract: A computer-implemented method for determining a treatment schedule for treating an agricultural field, comprising the following steps: (step A1) receiving by the computing unit – from a database and/or from user input and/or from real-time measurements – crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s) and indicative of at least one crop parameter, and- field data relating to the field(s) or sub-field zone(s) and indicative of at least one field environment parameter and/or field farming parameter, and- soil data relating to the field(s) or sub-field zone(s) and indicative of at least one soil-carbon parameters and/or soil-physical parameter, - optionally regulatory data relating to the field(s) or the sub-field zone(s), (step A2) at least based on the crop data, and the field data, and the soil data, generating a soil-related sustainability score for a field or a sub-field zone using a scoring model, wherein the scoring model is dependent on the following parameter groups: (PG1) crop parameter(s), (PG2) soil-carbon parameter(s), and/or soil-physical parameter(s), and (PG3) field environment parameter(s), and/or field farming parameter(s), (step A3) determining at least one treatment schedule based on the generated soil-related sustainability score.

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COMPUTER-IMPLEMENTED METHOD FOR DETERMINING A TREATMENT SCHEDULE
BASED ON A SOIL-RELATED SUSTAINABILITY SCORE AS TECHNICAL INDICATOR FOR
CARBON FARMING POTENTIAL OF AN AGRICULTURAL FIELD OR A SUB-FIELD ZONE
FIELD OF THE INVENTION

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The present invention relates to a method for generating a soil-related sustainability score for a field or a sub-field zone and the use of such a soil-related sustainability score for planning or conducting a treatment in a field or a sub-field zone or for controlling an agricultural equipment.

10 BACKGROUND OF THE INVENTION

From the perspective of a farmer, there is a need to assess whether his/her field has a potential for carbon farming, as well as to assess the impact of the certain treatment to the soil and to the soil-related sustainability, in order to select the most appropriate treatments. Up to now, there is no simple tool to conduct such assessment and such selection. Up to now, there is also no treatment mechanism that allows for reducing carbon footprint and via that the impact on the environment. The farmers usually act on the basis of their personal experience.

In view of this, it is found that a further need exists to simplify such a selection of treatment schedules. Additionally, it is found that there is a further need to provide methods which are more effective than the known methods to reduce impact on the environment.

SUMMARY OF THE INVENTION

In the view of the above, it is an object of the present invention to provide a method which enables more robust or more reliable field treatment, emission-reduced field treatment or environmental-friendly field treatment. In the view of the above, it is an object of the present invention to provide a method for assessing the soil-related sustainability and selecting or ranking treatment schedules according to the soil-related sustainability, which can be easily applied by a user and by which a respective treatment schedule recommendation is provided to a user, or by which the highest ranked treatment schedule is provided to a user. These and other objects, which become apparent upon reading the following description, are solved by the subject matter of the independent claims. The dependent claims refer to preferred embodiments of the invention.

35 According to a **first aspect** of the present invention, the present invention relates to:

A computer-implemented method for determining a treatment schedule for treating an agricultural field, comprising the following steps:

- 40 (step A1) receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –
- crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s) and indicative of at least one crop parameter, and
 - field data relating to the field(s) or sub-field zone(s) and indicative of at least one field environment parameter and/or field farming parameter, and

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- soil data relating to the field(s) or sub-field zone(s) and indicative of at least one soil-carbon parameters and/or soil-physical parameter,
 - optionally regulatory data relating to the field(s) or the sub-field zone(s),
- (step A2) at least based on the crop data, and the field data, and the soil data, generating a soil-related sustainability score for a field or a sub-field zone using a scoring model, wherein the scoring model is dependent on the following parameter groups:
- (PG1) crop parameter(s),
 - (PG2) soil-carbon parameter(s), and/or soil-physical parameter(s), and
 - (PG3) field environment parameter(s), and/or field farming parameter(s),
- (step A3) determining at least one treatment schedule based on the generated soil-related sustainability score.

According to a preferred embodiment of the present invention, the computer-implemented method further comprises

- (step A4) based on the determined treatment schedule, outputting a control file usable for controlling an agricultural equipment which can be used to treat the agricultural field.

According to a further preferred embodiment of the present invention, the soil data are indicative of at least one soil-carbon parameter and at least one soil-physical parameter, and the scoring model is dependent on the following parameter groups:

- (PG1) crop parameter(s),
- (PG2) soil-carbon parameter(s), and soil-physical parameter(s),
- (PG3) field environment parameter(s), and/or field farming parameter(s).

According to a further preferred embodiment of the present invention, the field data are indicative of at least one field environment parameter and at least one field farming parameter, and the scoring model is dependent on the following parameter groups:

- (PG1) crop parameter(s),
- (PG2) soil-carbon parameter(s), and/or soil-physical parameter(s),
- (PG3) field environment parameter(s), and field farming parameter(s).

According to a further preferred embodiment of the present invention, the soil data are indicative of at least one soil-carbon parameter and at least one soil-physical parameter, and the field data are indicative of at least one field environment parameter and at least one field farming parameter, and wherein the scoring model is dependent on the following parameter groups:

- (PG1) crop parameter(s),
- (PG2) soil-carbon parameter(s), and soil-physical parameter(s),
- (PG3) field environment parameter(s), and field farming parameter(s).

According to a further preferred embodiment of the present invention, the soil-carbon parameter is soil organic matter concentration, soil organic matter stock, soil organic carbon concentration, soil organic carbon stock, total carbon concentration, and/or total carbon stock of the soil in the field(s) or sub-field zone(s). Concentration is usually indicated in the unit "gram per kilogram soil", stock is usually indicated in the unit "kilogram per hectare" or "ton per hectare".

According to a further preferred embodiment of the present invention, the soil-physical parameter is soil type, soil quality, soil sandiness, soil moisture, soil humidity, soil temperature, soil surface temperature, soil texture, soil taxonomy, soil texture class, soil conductivity, soil fertility, soil pH value, and/or the water holding capacity of the soil in the field(s) or sub-field zone(s).

According to a further preferred embodiment of the present invention, the field environment parameter is climate status and/or condition, weather status and/or condition, temperature, air

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temperature, soil temperature, soil surface temperature, canopy temperature, humidity, air humidity, relative humidity, precipitation, moisture, wind condition, wind speed, sunlight level, likelihood of drought, likelihood of floods, or likelihood of extreme weather conditions relating to the field(s) or sub-field zone(s).

According to a further preferred embodiment of the present invention, the field farming parameter is the application of crop protection or crop nutrition products on the field(s) or on the sub-field zone(s) in the past, growth of plants on the field(s) or on the sub-field zone(s) in the past, pre-season soil treatment on the field(s) or on the sub-field zone(s), historic or current land use, soil conservation practices – including the degree or extent of direct seeding and/or tillage and/or ploughing treatment – of the soil, the type of cultivation of the field(s) or sub-field zone(s).

According to a further preferred embodiment of the present invention, the crop parameter is

a) crop species or variety of the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), preferably including genetic information of such crop, and/or

b) crop value of the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), preferably including oil content, protein content, and/or nutrient content of such crop, and/or

c) crop growth relating to the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), preferably including days to sexual maturity, vigor, emergence rating of such crop, growth stage (e.g. BBCH) of a crop, and/or

d) type of crops to be planted on the field(s) or on the sub-field zone(s), wherein the type of crops is either an annual crop or a perennial crop, and/or

e) the growth or non-growth of cover crops on the field(s) or on the sub-field zone(s).

According to a further preferred embodiment of the present invention, the crop parameter is the growth or non-growth of cover crops on the field(s) or on the sub-field zone(s).

According to a further preferred embodiment of the present invention, the soil-carbon parameter is the soil organic carbon content of the soil in the field(s) or sub-field zone(s).

According to a further preferred embodiment of the present invention, the soil-physical parameter is the soil type or soil texture of the soil in the field(s) or sub-field zone(s).

According to a further preferred embodiment of the present invention, the field environment parameter is the likelihood of drought relating to the field(s) or sub-field zone(s).

According to a further preferred embodiment of the present invention, the field farming parameter is the soil conservation practice – including the degree of direct seeding and/or tillage and/or ploughing treatment – of the soil.

According to a further preferred embodiment of the present invention,

- the crop parameter is the growth or non-growth of cover crops on the field(s) or on the sub-field zone(s), and/or

- the soil-carbon parameter is the soil organic carbon content of the soil in the field(s) or sub-field zone(s), and/or

- the soil-physical parameter is the soil type or soil texture of the soil in the field(s) or sub-field zone(s), and/or

- the field environment parameter is the likelihood of drought relating to the field(s) or sub-field zone(s), and/or

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- the field farming parameter is the soil conservation practice – including the degree of direct seeding and/or tillage and/or ploughing treatment – of the soil.

According to a further preferred embodiment of the present invention,

- the crop parameter is the growth or non-growth of cover crops on the field(s) or on the sub-field zone(s), and
- the soil-carbon parameter is the soil organic carbon content of the soil in the field(s) or sub-field zone(s), and
- the soil-physical parameter is the soil type or soil texture of the soil in the field(s) or sub-field zone(s), and
- the field environment parameter is the likelihood of drought relating to the field(s) or sub-field zone(s), and
- the field farming parameter is the soil conservation practice – including the degree of direct seeding and/or tillage and/or ploughing treatment – of the soil.

According to a preferred embodiment of the present invention, the crop data relating to the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s) include:

- a) crop species or variety data of the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), wherein the crop species or variety data preferably includes genetic information of such crop, and/or
- b) crop value data of the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), wherein the crop value data preferably includes oil content, protein content, and/or nutrient content of such crop, and/or
- c) crop agronomic data relating to the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), wherein the crop agronomic data preferably includes days to sexual maturity, vigor, emergence rating of such crop, growth stage (e.g. BBCH) of a crop, and/or
- d) crop regulatory data relating to the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), wherein the crop regulatory data preferably includes region-specific information on the legal framework and/or regulations relating to the method or product used for treatment, region-specific information on measures of product stewardship, information on biodiversity regulations or biodiversity measures,
- e) crop stress data relating to the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), wherein the crop stress data preferably includes data relating to the historic or current or expected or simulated presence of (i) fungi (“fungal plant disease”), (ii) bacteria and/or viruses (“bacterial and/or viral plant disease”), (iii) weeds, (iv) insects – including arachnids, molluscs, and/or nematodes – or insect feeding damage, (v) plant nutrition deficiencies, (vi) heat stress, for example temperature conditions higher than 30°C, (vii) cold stress, for example temperature conditions lower than 10°C, (viii) drought stress, (ix) exposure to excessive sun light, for example exposure to sun light causing signs of scorch, sun burn or similar signs of irradiation, (x) acidic or alkaline pH conditions in the soil with pH values lower than pH 5 and/or pH values higher than 9, (xi) salt stress, for example soil salinity, (xii) pollution with chemicals, for example with heavy metals, (xiii) fertilizer or crop protection adverse effects, for example herbicide injuries, (xiv) destructive weather conditions, for example hail, frost, damaging wind.

According to a preferred embodiment of the present invention, the field data relating to the field(s) or sub-field zone(s) include:

- a) field geographical data relating to the field(s) or sub-field zone(s), wherein the field geographical data include GPS (Global Positioning System), geographical location data,

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geographical positioning data, altitude, elevation, slope, and/or relief data relating to the field(s) or sub-field zone(s), and/or

b) field farming data relating to the field(s) or sub-field zone(s), wherein the field farming data preferably include data relating to the application of crop protection or crop nutrition products on the field(s) or on the sub-field zone(s) in the past, data relating to the growth of plants on the field(s) or on the sub-field zone(s) in the past, data regarding the historic or pre-season soil treatment on the field(s) or on the sub-field zone(s), data regarding the historic or current land use, data regarding the seeding or planting of annual or perennial crops, data regarding direct seeding and/or tillage and/or ploughing treatment of the soil, and/or data regarding the type of cultivation of the field(s) or sub-field zone(s),

c) field environmental data relating to the field(s) or sub-field zone(s), wherein the field environmental data preferably include climate status and/or condition, weather status and/or condition, temperature, air temperature, soil temperature, soil surface temperature, canopy temperature, humidity, air humidity, relative humidity, precipitation, moisture, wind condition, wind speed, sunlight level data, likelihood of drought, likelihood of floods, or likelihood of extreme weather conditions, or biodiversity relating to the field(s) or sub-field zone(s).

The field data, especially the field farming data and the field environmental data (especially the climate and weather-related data) may be historic data, real actual data (e.g. obtained from sensors), predicted data or forecast data.

According to a preferred embodiment of the present invention, the soil data relating to the field(s) or sub-field zone(s) are data indicative of the biological, biochemical, chemical, and/or physical properties of the soil in the field(s) or sub-field zone(s).

According to a preferred embodiment of the present invention, the soil data relating to the field(s) or sub-field zone(s) include:

a) soil organic matter concentration, soil organic matter stock, soil organic carbon concentration, soil organic carbon stock, total carbon concentration, and/or total carbon stock of the soil in the field(s) or sub-field zone(s); and/or

b) soil type, soil quality, soil sandiness, soil moisture, soil humidity, soil temperature, soil surface temperature, soil texture, soil taxonomy, soil texture class, soil conductivity, soil fertility, soil pH value, and/or water holding capacity of the soil in the field(s) or sub-field zone(s).

According to a preferred embodiment of the present invention, the regulatory data relating to the field(s) or sub-field zone(s) include:

data regarding the requirements of and/or eligibility for carbon farming programs or contracts, data regarding the methodologies of carbon farming programs or contracts, data regarding the legal framework for carbon farming in specific countries, data regarding the requirements of and/or eligibility for sustainability programs or contracts, data regarding the methodologies of sustainability programs or contracts, data regarding the legal framework for sustainability programs or contracts in specific countries, data regarding the requirements of and/or eligibility for organic farming programs or contracts, data regarding the methodologies of organic farming programs or contracts, data regarding the legal framework for organic farming in specific countries, data regarding the requirements of and/or eligibility for climate smart farming programs or contracts,

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data regarding the methodologies of climate smart farming programs or contracts, data regarding the legal framework for climate smart farming in specific countries, data regarding the requirements of and/or eligibility for regenerative farming programs or contracts, data regarding the methodologies of regenerative farming programs or contracts, data regarding the legal framework of regenerative farming in specific countries, data regarding the requirements and/or eligibility for agroecology programs or contracts, data regarding the methodologies of agroecology programs or contracts, data regarding the legal framework of agroecology in specific countries, data regarding the requirements of and/or eligibility for agroforestry programs or contracts, data regarding the methodologies of agroforestry programs or contracts, data regarding the legal framework of agroforestry in specific countries, data regarding the requirements of and/or eligibility for integrated farming programs, data regarding the methodologies of integrated farming programs, and/or data regarding the legal framework of integrated farming in specific countries.

In this context, methodologies preferably include the technical methods (including calculation methods), strategies and systems relating to the relevant programs or contracts.

According to a preferred embodiment of the present invention, the regulatory data relating to the field(s) or sub-field zone(s) more preferably include:

data regarding the requirements of and/or eligibility for carbon farming programs or contracts, data regarding the methodologies of carbon farming programs or contracts, data regarding the legal framework for carbon farming in specific countries.

According to a preferred embodiment of the present invention, the regulatory data relating to the field(s) or sub-field zone(s) more preferably include:

data regarding the requirements of and/or eligibility for sustainability programs or contracts, data regarding the methodologies of sustainability programs or contracts, data regarding the legal framework for sustainability programs or contracts in specific countries.

According to a preferred embodiment of the present invention, the product used for the treatment and/or in the treatment schedule is selected from the group consisting of fungicide, herbicide, insecticide, acaricide, molluscicide, nematocide, avicide, piscicide, rodenticide, repellent, bactericide, biocide, safener, plant growth regulator, urease inhibitor, nitrification inhibitor, denitrification inhibitor, fertilizer, nutrient, inoculants, biofungicide, bioherbicide, bioinsecticide, biological acaricide, biological molluscicide, biological nematocide, biological avicide, biological piscicide, biological rodenticide, biological repellent, biological bactericide, biological biocide, biological safener, biological plant growth regulator, biological urease inhibitor, biological nitrification inhibitor, biological denitrification inhibitor, seeds, and/or any combination thereof. More preferably, product used for the treatment is a fungicide, herbicide, insecticide, acaricide, molluscicide, nematocide, and/or any combination thereof. In another more preferred embodiment, the product used for the treatment is a urease inhibitor, nitrification inhibitor, denitrification inhibitor, fertilizer, nutrient, and/or any combination thereof. In another more preferred embodiment, the product used for the treatment is seed, particularly seeds of crop plants and/or seeds of cover plants and/or seeds of

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other plants which can contribute to the improvement of soil quality or sustainability. In another more preferred embodiment, the product is identified by product identifiers (product IDs), which can be recognized by the computing system or inputted into the scoring model.

5 According to a further preferred embodiment of the present invention, a data processing system comprising means for carrying out the computer-implemented method according to one of the above embodiments of the invention was found.

10 According to a further preferred embodiment of the present invention, a computer program product comprising instructions which, when the program is executed by a computer, cause the computer to carry out the computer-implemented method according to anyone of the above embodiments of the invention was found.

15 According to a further preferred embodiment of the present invention, a computer-readable storage medium comprising instructions which, when executed by a computer, cause the computer to carry out the computer-implemented method according to anyone of the above embodiments of the invention was found.

20 According to a **second aspect** of the present invention, the present invention relates to:

A computer-implemented method for determining a treatment schedule for treating an agricultural field, comprising the following steps:

- 25 (step A1') receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –
- crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and
 - field data relating to the field(s) or sub-field zone(s), and
 - 30 - soil data relating to the field(s) or sub-field zone(s), and
 - optionally regulatory data relating to the field(s) or the sub-field zone(s),
- (step A2') at least based on the crop data, and the field data, and the soil data, initiating and/or performing data processing in at least one database and/or database system containing
- 35 - data related to crop data, and
 - data related to field data, and
 - data related to soil data, and
 - optionally data related to regulatory data,
- (step A3') based on the result of the data processing, outputting the soil-related sustainability score.
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According to a **third aspect** of the present invention, the present invention relates to:

45 a computer-implemented method for generating a soil-related sustainability score for a field or a sub-field zone:

- (step A1') receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –

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- crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and
- field data relating to the field(s) or sub-field zone(s), and
- soil data relating to the field(s) or sub-field zone(s), and
- 5 (step A2') optionally regulatory data relating to the field(s) or the sub-field zone(s), at least based on the crop data, and the field data, and the soil data, initiating and/or performing data processing in at least one database and/or database system containing
 - data related to crop data, and
 - 10 - data related to field data, and
 - data related to soil data, and
 - optionally data related to regulatory data,
- 15 (step A3') based on the result of the data processing, outputting the soil-related sustainability score;
- (step B) generating at least one treatment schedule for treating the field(s) or sub-field zone(s) by the following steps B1 to B3, wherein a treatment schedule comprises
 - (i) at least one treatment,
 - 20 (ii) at least one time window used for each treatment, and
 - (iii) at least one method and/or product used for each treatment,
- (step B1) receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –
 - 25 - crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and
 - field data relating to the field(s) or sub-field zone(s), and
 - soil data relating to the field(s) or sub-field zone(s),
- 30 (step B2) at least based on the crop data, and the field data, and the soil data, initiating and/or performing data processing in at least one database and/or database system containing
 - data related to crop data, and
 - data related to field data, and
 - data related to soil data, and
 - data related to the treatment schedule,
- 35 (step B3) based on the result of the data processing, outputting the at least one treatment schedule for generating the simulated soil-related sustainability score;
- (step C) generating a simulated soil-related sustainability score relating to the at least one treatment schedule for a field or sub-field zone, comprising the following steps C1 to C4:
- 40 (step C1) receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –
 - 45 - crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and
 - field data relating to the field(s) or sub-field zone(s), and
 - soil data relating to the field(s) or sub-field zone(s), and

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- data related to the treatment schedule,
- optionally regulatory data relating to the field(s) or sub-field zone(s),
- (step C2) modifying the crop data, field data and/or soil data using a simulation based on
 - 5 - the data related to the treatment schedule and
 - the assumption that a treatment will be conducted according to the at least one treatment schedule,
- (step C3) at least based on the (if applicable: modified) crop data, and the (if applicable: modified) field data, and the (if applicable: modified) soil data,
 - 10 initiating and/or performing data processing in at least one database and/or database system containing
 - data related to crop data, and
 - data related to field data, and
 - data related to soil data, and
 - 15 - optionally data related to regulatory data,
- (step C4) based on the result of the data processing, outputting the simulated soil-related sustainability score relating to the at least one treatment schedule;
- (step D) generating the score improvement value relating to the at least one treatment schedule by calculating the difference between the simulated soil-related sustainability score relating to the at least one treatment schedule and the soil-related sustainability score,
- (step F) outputting
 - 25 - the at least one treatment schedule together with its score improvement value, or
 - the score improvement value relating to the at least one treatment schedule.

According to a **fourth aspect** of the present invention, the present invention relates to:

30 a computer-implemented method for generating a soil-related sustainability score for a field or a sub-field zone, comprising the following steps:

- (step A1') receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –
 - 35 - crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and
 - field data relating to the field(s) or sub-field zone(s), and
 - soil data relating to the field(s) or sub-field zone(s), and
 - 40 - optionally regulatory data relating to the field(s) or the sub-field zone(s),
- (step A2') at least based on the crop data, and the field data, and the soil data, initiating and/or performing data processing in at least one database and/or database system containing
 - 45 - data related to crop data, and
 - data related to field data, and
 - data related to soil data, and

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- optionally data related to regulatory data,
 (step A3') based on the result of the data processing, outputting the soil-related sustainability score;

(step B) receiving by the computing unit – from a database and/or from user input and/or from real-time measurements – at least one treatment schedule for treating the field(s) or sub-field zone(s) wherein a treatment schedule comprises

- (i) at least one treatment,
- (ii) at least one time window used for each treatment, and
- (iii) at least one method and/or product used for each treatment,

(step C) generating a simulated soil-related sustainability score relating to the at least one treatment schedule for a field or sub-field zone, comprising the following steps C1 to C4:

(step C1) receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –

- crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and
- field data relating to the field(s) or sub-field zone(s), and
- soil data relating to the field(s) or sub-field zone(s), and
- data related to the treatment schedule,
- optionally regulatory data relating to the field(s) or sub-field zone(s),

(step C2) modifying the crop data, field data and/or soil data using a simulation based on

- the data related to the treatment schedule and
- the assumption that a treatment will be conducted according to the at least one treatment schedule,

(step C3) at least based on the (if applicable: modified) crop data, and the (if applicable: modified) field data, and the (if applicable: modified) soil data, initiating and/or performing data processing in at least one database and/or database system containing

- data related to crop data, and
- data related to field data, and
- data related to soil data, and
- optionally data related to regulatory data,

(step C4) based on the result of the data processing, outputting the simulated soil-related sustainability score relating to the at least one treatment schedule;

(step D) generating the score improvement value relating to the at least one treatment schedule by calculating the difference between the simulated soil-related sustainability score relating to the at least one treatment schedule and the soil-related sustainability score, wherein the score improvement value is the difference between the simulated soil-related sustainability score relating to the at least one treatment schedule and the soil-related sustainability score,

(step F) outputting

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- the at least one treatment schedule together with its score improvement value, and/or
- the score improvement value relating to the at least one treatment schedule.

5 According to a preferred embodiment of the present invention, the computer-implemented method further comprises the following steps:

(step E) predefining at least one minimum threshold for the score improvement value,

10 and wherein in (step F), only the treatment schedules for which the score improvement values have exceeded the minimum threshold and/or only the score improvement values which have exceeded the minimum threshold are outputted.

15 The threshold may be preferably predefined as +1, +2, +3, +4 or +5, in case the soil-related sustainability score is a numeric value ranging from 0 (lowest) to 100 (highest).

According to a preferred embodiment of the present invention, at least two treatment schedules are generated or received.

20 According to a preferred embodiment of the present invention, at least two treatment schedules are generated or received and the at least two treatment schedules are ranked according to their score improvement value.

25 According to a preferred embodiment of the present invention, at least five treatment schedules are generated or received and the at least five treatment schedules are ranked according to their score improvement value.

30 According to a preferred embodiment of the present invention, at least ten treatment schedules are generated or received and the at least ten treatment schedules are ranked according to their score improvement value.

35 According to a preferred embodiment of the present invention, at least two treatment schedules are generated or received and the at least two treatment schedules are ranked according to their score improvement value and the treatment schedule with the highest score improvement value is outputted or further processed as a control signal or control file for an agricultural equipment, wherein the agricultural equipment is preferably a seed drill, planter, or sprayer.

40 According to a preferred embodiment of the present invention, a data processing system comprising means for carrying out the computer-implemented method according to the present invention was found.

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According to a preferred embodiment of the present invention, a computer program product comprising instructions which, when the program is executed by a computer, cause the computer to carry out the computer-implemented method according to the present invention was found.

According to a preferred embodiment of the present invention, a computer-readable storage medium comprising instructions which, when executed by a computer, cause the computer to carry out the computer-implemented method according to the present invention was found.

According to a preferred embodiment of the present invention, the use of the soil-related sustainability score determined by the computer-implemented method according to the present invention for planning or conducting a treatment in a field or a sub-field zone or for controlling an agricultural equipment was found.

Further aspects and further preferred embodiments of the present invention are also the below Embodiments.

Embodiment 1:

A computer-implemented method for generating a soil-related sustainability score for a field or a sub-field zone, comprising the following steps:

(step A1') receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –

- crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and
- field data relating to the field(s) or sub-field zone(s), and
- soil data relating to the field(s) or sub-field zone(s), and
- optionally regulatory data relating to the field(s) or the sub-field zone(s),

(step A2') at least based on the crop data, and the field data, and the soil data, initiating and/or performing data processing in at least one database and/or database system containing

- data related to crop data, and
- data related to field data, and
- data related to soil data, and
- optionally data related to regulatory data,

(step A3') based on the result of the data processing, outputting the soil-related sustainability score.

Embodiment 1a:

A computer-implemented method for generating a soil-related sustainability score for a field or a sub-field zone, comprising the following steps:

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(step A1') receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –

- crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and
- field data relating to the field(s) or sub-field zone(s), and
- soil data relating to the field(s) or sub-field zone(s), and
- regulatory data relating to the field(s) or the sub-field zone(s),

(step A2') at least based on the crop data, and the field data, and the soil data, initiating and/or performing data processing in at least one database and/or database system containing

- data related to crop data, and
- data related to field data, and
- data related to soil data, and
- data related to regulatory data,

(step A3') based on the result of the data processing, outputting the soil-related sustainability score.

Embodiment 2:

Computer-implemented method according to Embodiment 1 or 1a, further comprising the following steps:

(step B) generating at least one treatment schedule for treating the field(s) or sub-field zone(s) by the following steps B1 to B3, wherein a treatment schedule comprises

- (i) at least one treatment,
- (ii) at least one time window used for each treatment, and
- (iii) at least one method and/or product used for each treatment,

(step B1) receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –

- crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and
- field data relating to the field(s) or sub-field zone(s), and
- soil data relating to the field(s) or sub-field zone(s),

(step B2) at least based on the crop data, and the field data, and the soil data, initiating and/or performing data processing in at least one database and/or database system containing

- data related to crop data, and
- data related to field data, and
- data related to soil data, and
- data related to the treatment schedule,

(step B3) based on the result of the data processing, outputting the at least one treatment schedule for generating the simulated soil-related sustainability score;

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(step C) generating a simulated soil-related sustainability score relating to the at least one treatment schedule for a field or sub-field zone, comprising the following steps C1 to C4:

- 5 (step C1) receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –
- crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and
 - field data relating to the field(s) or sub-field zone(s), and
 - 10 - soil data relating to the field(s) or sub-field zone(s), and
 - data related to the treatment schedule,
 - optionally regulatory data relating to the field(s) or sub-field zone(s),
- (step C2) modifying the crop data, field data and/or soil data using a simulation based on
- 15 - the data related to the treatment schedule and
 - the assumption that a treatment will be conducted according to the at least one treatment schedule,
- (step C3) at least based on the (if applicable: modified) crop data, and the (if applicable: modified) field data, and the (if applicable: modified) soil data, initiating and/or performing data processing in at least one database and/or database system containing
- 20 - data related to crop data, and
 - data related to field data, and
 - data related to soil data, and
 - 25 - optionally data related to regulatory data,
- (step C4) based on the result of the data processing, outputting the simulated soil-related sustainability score relating to the at least one treatment schedule;
- (step D) generating the score improvement value relating to the at least one treatment schedule by calculating the difference between the simulated soil-related sustainability score relating to the at least one treatment schedule and the soil-related sustainability score,
- 30 (step F) outputting
- 35 - the at least one treatment schedule together with its score improvement value, or
 - the score improvement value relating to the at least one treatment schedule.

Embodiment 2a:

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Computer-implemented method according to Embodiment 1 or 1a, further comprising the following steps:

- 45 (step B) generating at least one treatment schedule for treating the field(s) or sub-field zone(s) by the following steps B1 to B3, wherein a treatment schedule comprises
- (i) at least one treatment,
 - (ii) at least one time window used for each treatment, and
 - (iii) at least one method and/or product used for each treatment,

15

- (step B1) receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –
- crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and
 - 5 - field data relating to the field(s) or sub-field zone(s), and
 - soil data relating to the field(s) or sub-field zone(s),
- (step B2) at least based on the crop data, and the field data, and the soil data, initiating and/or performing data processing in at least one database and/or database system containing
- 10 - data related to crop data, and
 - data related to field data, and
 - data related to soil data, and
 - data related to the treatment schedule,
- (step B3) based on the result of the data processing, outputting the at least one treatment schedule for generating the simulated soil-related sustainability score;
- 15
- (step C) generating a simulated soil-related sustainability score relating to the at least one treatment schedule for a field or sub-field zone, comprising the following steps C1 to C4:
- 20
- (step C1) receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –
- 25 - crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and
 - field data relating to the field(s) or sub-field zone(s), and
 - soil data relating to the field(s) or sub-field zone(s), and
 - data related to the treatment schedule,
 - regulatory data relating to the field(s) or sub-field zone(s),
- 30 (step C2) modifying the crop data, field data and/or soil data using a simulation based on
- the data related to the treatment schedule and
 - the assumption that a treatment will be conducted according to the at least one treatment schedule,
- 35 (step C3) at least based on the (if applicable: modified) crop data, and the (if applicable: modified) field data, and the (if applicable: modified) soil data, initiating and/or performing data processing in at least one database and/or database system containing
- 40 - data related to crop data, and
 - data related to field data, and
 - data related to soil data, and
 - data related to regulatory data,
- (step C4) based on the result of the data processing, outputting the simulated soil-related sustainability score relating to the at least one treatment schedule;
- 45
- (step D) generating the score improvement value relating to the at least one treatment schedule by calculating the difference between the simulated soil-related

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sustainability score relating to the at least one treatment schedule and the soil-related sustainability score,

(step F) outputting

- 5 - the at least one treatment schedule together with its score improvement value, or
- the score improvement value relating to the at least one treatment schedule.

10 Embodiment 3:

Computer-implemented method according to Embodiment 1 or 1a, further comprising the following steps:

15 (step B') receiving by the computing unit – from a database and/or from user input and/or from real-time measurements – at least one treatment schedule for treating the field(s) or sub-field zone(s) wherein a treatment schedule comprises

- 20 (i) at least one treatment,
- (ii) at least one time window used for each treatment, and
- (iii) at least one method and/or product used for each treatment,

 (step C) generating a simulated soil-related sustainability score relating to the at least one treatment schedule for a field or sub-field zone, comprising the following steps C1 to C4:

 (step C1) receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –

- 30 - crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and
- field data relating to the field(s) or sub-field zone(s), and
- soil data relating to the field(s) or sub-field zone(s), and
- data related to the treatment schedule,
- optionally regulatory data relating to the field(s) or sub-field zone(s),

35 (step C2) modifying the crop data, field data and/or soil data using a simulation based on

- the data related to the treatment schedule and
- the assumption that a treatment will be conducted according to the at least one treatment schedule,

40 (step C3) at least based on the (if applicable: modified) crop data, and the (if applicable: modified) field data, and the (if applicable: modified) soil data, initiating and/or performing data processing in at least one database and/or database system containing

- 45 - data related to crop data, and
- data related to field data, and
- data related to soil data, and
- optionally data related to regulatory data,

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(step C4) based on the result of the data processing, outputting the simulated soil-related sustainability score relating to the at least one treatment schedule;

(step D) generating the score improvement value relating to the at least one treatment schedule by calculating the difference between the simulated soil-related sustainability score relating to the at least one treatment schedule and the soil-related sustainability score, wherein the score improvement value is the difference between the simulated soil-related sustainability score relating to the at least one treatment schedule and the soil-related sustainability score,

(step F) outputting

- the at least one treatment schedule together with its score improvement value, and/or
- the score improvement value relating to the at least one treatment schedule.

Embodiment 3a:

Computer-implemented method according to Embodiment 1 or 1a, further comprising the following steps:

(step B') receiving by the computing unit – from a database and/or from user input and/or from real-time measurements – at least one treatment schedule for treating the field(s) or sub-field zone(s) wherein a treatment schedule comprises

- (i) at least one treatment,
- (ii) at least one time window used for each treatment, and
- (iii) at least one method and/or product used for each treatment,

(step C) generating a simulated soil-related sustainability score relating to the at least one treatment schedule for a field or sub-field zone, comprising the following steps C1 to C4:

(step C1) receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –

- crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and
- field data relating to the field(s) or sub-field zone(s), and
- soil data relating to the field(s) or sub-field zone(s), and
- data related to the treatment schedule,
- regulatory data relating to the field(s) or sub-field zone(s),

(step C2) modifying the crop data, field data and/or soil data using a simulation based on

- the data related to the treatment schedule and
- the assumption that a treatment will be conducted according to the at least one treatment schedule,

(step C3) at least based on the (if applicable: modified) crop data, and the (if applicable: modified) field data, and the (if applicable: modified) soil data, initiating and/or performing data processing in at least one database and/or database system containing

- data related to crop data, and

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- data related to field data, and
- data related to soil data, and
- data related to regulatory data,

(step C4) based on the result of the data processing, outputting the simulated soil-related sustainability score relating to the at least one treatment schedule;

(step D) generating the score improvement value relating to the at least one treatment schedule by calculating the difference between the simulated soil-related sustainability score relating to the at least one treatment schedule and the soil-related sustainability score, wherein the score improvement value is the difference between the simulated soil-related sustainability score relating to the at least one treatment schedule and the soil-related sustainability score,

(step F) outputting

- the at least one treatment schedule together with its score improvement value, and/or
- the score improvement value relating to the at least one treatment schedule.

Embodiment 4:

Computer-implemented method according to Embodiment 2 or 2a or 3 or 3a, further comprising the following steps:

(step E) predefining at least one minimum threshold for the score improvement value, and wherein in (step F), only the treatment schedules for which the score improvement values have exceeded the minimum threshold and/or only the score improvement values which have exceeded the minimum threshold are outputted.

Embodiment 5:

Computer-implemented method according to anyone of the Embodiments 2 to 4, wherein at least two treatment schedules are generated or received.

Embodiment 6:

Computer-implemented method according to anyone of the Embodiments 2 to 4, wherein at least two treatment schedules are generated or received and wherein the at least two treatment schedules are ranked according to their score improvement value.

Embodiment 7:

Computer-implemented method according to anyone of the Embodiments 2 to 4, wherein at least two treatment schedules are generated or received and wherein the at least two treatment schedules are ranked according to their score improvement value and wherein the treatment

schedule with the highest score improvement value is outputted or further processed as a control signal or control file for an agricultural equipment, wherein the agricultural equipment is preferably a seed drill, planter, or sprayer.

5 Embodiment 8:

Computer-implemented method according to anyone of the preceding Embodiments, wherein the crop data relating to the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s) include:

- 10 a) crop species or variety data of the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), wherein the crop species or variety data preferably includes genetic information of such crop, and/or
- 15 b) crop value data of the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), wherein the crop value data preferably includes oil content, protein content, and/or nutrient content of such crop, and/or
- c) crop agronomic data relating to the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), wherein the crop agronomic data preferably includes days to sexual maturity, vigor, emergence rating of such crop, growth stage (e.g. BBCH) of a crop, and/or
- 20 d) crop regulatory data relating to the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), wherein the crop regulatory data preferably includes region-specific information on the legal framework and/or regulations relating to the method or product used for treatment, region-specific information on measures of product stewardship, information on biodiversity regulations or biodiversity measures,
- 25 e) crop stress data relating to the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), wherein the crop stress data preferably includes data relating to the historic or current or expected or simulated presence of (i) fungi ("fungal plant disease"), (ii) bacteria and/or viruses ("bacterial and/or viral plant disease"), (iii) weeds, (iv) insects – including arachnids, molluscs, and/or nematodes – or insect feeding damage, (v) plant nutrition deficiencies, (vi) heat stress, for example temperature conditions higher than 30°C, (vii) cold stress, for example temperature conditions lower than 10°C, (viii) drought stress, (ix) exposure to excessive sun light, for example exposure to sun light causing signs of scorch, sun burn or similar signs of irradiation, (x) acidic or alkaline pH conditions in the soil with pH values lower than pH 5 and/or pH values higher than 9, (xi) salt stress, for example soil salinity, (xii) pollution with chemicals, for example with heavy metals, (xiii) fertilizer or crop protection adverse effects,
- 30 for example herbicide injuries, (xiv) destructive weather conditions, for example hail, frost, damaging wind.
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Embodiment 9:

- 40 Computer-implemented method according to anyone of the preceding Embodiments, wherein the crop data relating to the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s) include: crop species or variety data and/or growth stage (e.g. BBCH) of a crop.

45 Embodiment 10:

Computer-implemented method according to anyone of the preceding Embodiments, wherein the field data relating to the field(s) or sub-field zone(s) include:

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a) field geographical data relating to the field(s) or sub-field zone(s), wherein the field geographical data include GPS (Global Positioning System), geographical location data, geographical positioning data, altitude, elevation, slope, and/or relief data relating to the field(s) or sub-field zone(s), and/or

5 b) field farming data relating to the field(s) or sub-field zone(s), wherein the field farming data preferably include data relating to the application of crop protection or crop nutrition products on the field(s) or on the sub-field zone(s) in the past, data relating to the growth of plants on the field(s) or on the sub-field zone(s) in the past, data regarding the historic or pre-season soil treatment on the field(s) or on the sub-field zone(s), data regarding the historic or current land use, data regarding the seeding or planting of annual or perennial crops, data regarding direct seeding and/or tillage and/or ploughing treatment of the soil, and/or data regarding the type of cultivation of the field(s) or sub-field zone(s),

10 c) field environmental data relating to the field(s) or sub-field zone(s), wherein the field environmental data preferably include climate status and/or condition, weather status and/or condition, temperature, air temperature, soil temperature, soil surface temperature, canopy temperature, humidity, air humidity, relative humidity, precipitation, moisture, wind condition, wind speed, sunlight level data, likelihood of drought, likelihood of floods, or likelihood of extreme weather conditions, or biodiversity relating to the field(s) or sub-field zone(s).

20 Embodiment 11:

Computer-implemented method according to anyone of the preceding Embodiments, wherein the field data relating to the field(s) or sub-field zone(s) include:

25 data relating to the growth of plants on the field(s) or on the sub-field zone(s) in the past, data regarding the historic or pre-season soil treatment on the field(s) or on the sub-field zone(s), data regarding the historic or current land use, data regarding the seeding or planting of annual or perennial crops, data regarding direct seeding and/or tillage and/or ploughing treatment of the soil, and/or likelihood of drought.

30 Embodiment 12:

Computer-implemented method according to anyone of the preceding Embodiments, wherein the soil data relating to the field(s) or sub-field zone(s) are data indicative of the biological, biochemical, chemical, and/or physical properties of the soil in the field(s) or sub-field zone(s).

35 Embodiment 13:

Computer-implemented method according to anyone of the preceding Embodiments, wherein the soil data relating to the field(s) or sub-field zone(s) include:

40 a) soil organic matter concentration, soil organic matter stock, soil organic carbon concentration, soil organic carbon stock, total carbon concentration, and/or total carbon stock of the soil in the field(s) or sub-field zone(s); and/or

b) soil type, soil quality, soil sandiness, soil moisture, soil humidity, soil temperature, soil surface temperature, soil density, soil texture, soil taxonomy, soil texture class, soil conductivity, soil fertility, soil pH value, and/or water holding capacity of the soil in the field(s) or sub-field zone(s).

45 Embodiment 14:

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Computer-implemented method according to anyone of the preceding Embodiments, wherein the soil data relating to the field(s) or sub-field zone(s) include: soil organic matter, soil organic carbon, total carbon content, organic carbon content, phosphorus content, nitrogen content, soil type, soil quality, soil sandiness, and/or soil moisture

Embodiment 15:

Computer-implemented method according to anyone of the preceding Embodiments, wherein the soil data relating to the field(s) or sub-field zone(s) include: soil organic matter, soil organic carbon, total carbon content, organic carbon content, phosphorus content, and/or nitrogen content.

Embodiment 16:

Computer-implemented method according to anyone of the preceding Embodiments, wherein the soil data relating to the field(s) or sub-field zone(s) include: soil type, soil quality, soil sandiness, and/or soil moisture.

Embodiment 17:

Computer-implemented method according to anyone of the preceding Embodiments, wherein the regulatory data relating to the field(s) or sub-field zone(s) include: data regarding the requirements of and/or eligibility for carbon farming programs or contracts, data regarding the methodologies of carbon farming programs or contracts, data regarding the legal framework for carbon farming in specific countries, data regarding the requirements of and/or eligibility for sustainability programs or contracts, data regarding the methodologies of sustainability programs or contracts, data regarding the legal framework for sustainability programs or contracts in specific countries, data regarding the requirements of and/or eligibility for organic farming programs or contracts, data regarding the methodologies of organic farming programs or contracts, data regarding the legal framework for organic farming in specific countries, data regarding the requirements of and/or eligibility for climate smart farming programs or contracts, data regarding the methodologies of climate smart farming programs or contracts, data regarding the legal framework for climate smart farming in specific countries, data regarding the requirements of and/or eligibility for regenerative farming programs or contracts, data regarding the methodologies of regenerative farming programs or contracts, data regarding the legal framework of regenerative farming in specific countries, data regarding the requirements and/or eligibility for agroecology programs or contracts, data regarding the methodologies of agroecology programs or contracts, data regarding the legal framework of agroecology in specific countries, data regarding the requirements of and/or eligibility for agroforestry programs or contracts, data regarding the methodologies of agroforestry programs or contracts, data regarding the legal framework of agroforestry in specific countries, data regarding the requirements of and/or eligibility for integrated farming programs, data regarding the methodologies of integrated farming programs, and/or data regarding the legal framework of integrated farming in specific countries.

Embodiment 18:

Computer-implemented method according to anyone of the preceding Embodiments, wherein the regulatory data relating to the field(s) or sub-field zone(s) include:

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data regarding the requirements of carbon farming programs or contracts, data regarding the eligibility for carbon farming programs or contracts, data regarding the methodologies of carbon farming programs or contracts, data regarding the legal framework for carbon farming in specific countries.

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Embodiment 19:

Computer-implemented method according to anyone of the preceding Embodiments,

10 - wherein the crop data relating to the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s) include: crop species or variety data and/or growth stage (e.g. BBCH) of a crop.

- wherein the field data relating to the field(s) or sub-field zone(s) include: data relating to the growth of plants on the field(s) or on the sub-field zone(s) in the past, data regarding the historic or pre-season soil treatment on the field(s) or on the sub-field zone(s), data regarding the
15 historic or current land use, data regarding the seeding or planting of annual or perennial crops, data regarding direct seeding and/or tillage and/or ploughing treatment of the soil, and/or likelihood of drought.

- wherein the soil data relating to the field(s) or sub-field zone(s) include: soil organic matter, soil organic carbon, total carbon content, organic carbon content, phosphorus content, nitrogen
20 content, soil type, soil quality, soil sandiness, and/or soil moisture

- wherein the regulatory data relating to the field(s) or sub-field zone(s) include: data regarding the requirements of carbon farming programs or contracts, data regarding the eligibility for carbon farming programs or contracts, data regarding the methodologies of carbon farming programs or contracts, data regarding the legal framework for carbon farming in specific
25 countries,

Embodiment 20:

30 Computer-implemented method according to anyone of the preceding Embodiments, wherein the product used for the treatment is selected from the group consisting of fungicide, herbicide, insecticide, acaricide, molluscicide, nematocide, avicide, piscicide, rodenticide, repellent, bactericide, biocide, safener, plant growth regulator, urease inhibitor, nitrification inhibitor, denitrification inhibitor, fertilizer, nutrient, inoculants, biofungicide, bioherbicide, bioinsecticide,
35 biological acaricide, biological molluscicide, biological nematocide, biological avicide, biological piscicide, biological rodenticide, biological repellent, biological bactericide, biological biocide, biological safener, biological plant growth regulator, biological urease inhibitor, biological nitrification inhibitor, biological denitrification inhibitor, seeds, and/or any combination thereof.

40 Embodiment 21:

Computer-implemented method according to anyone of the preceding Embodiments, wherein a soil-related sustainability score is each generated for at least two fields or sub-field zones and said at least two fields or sub-field zones are ranked according to the soil-related sustainability
45 score.

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Embodiment 22:

5 Computer-implemented method according to anyone of the preceding Embodiments, wherein the soil-related sustainability scores are related to the sub-field zones and the sub-field zones are divided according to the different soil types.

Embodiment 23:

10 Computer-implemented method according to anyone of the preceding Embodiments, wherein the soil-related sustainability scores are related to the sub-field zones and the sub-field zones are divided according to the different soil parameters, such as soil organic matter.

Embodiment 24:

15 Data processing system comprising means for carrying out the computer-implemented method according to anyone of the Embodiments 1 to 23.

Embodiment 25:

20 A computer program product comprising instructions which, when the program is executed by a computer, cause the computer to carry out the computer-implemented method according to anyone of the Embodiments 1 to 23.

Embodiment 26:

25 A computer-readable storage medium comprising instructions which, when executed by a computer, cause the computer to carry out the computer-implemented method according to anyone of the Embodiments 1 to 23.

Embodiment 27:

30 Use of the soil-related sustainability score determined by the computer-implemented method according to anyone of the Embodiments 1 to 23 for planning or conducting a treatment in a field or a sub-field zone or for controlling an agricultural equipment.

#Definitions

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The soil-related sustainability score is preferably a score which represents the potential of a field or a sub-field for improving soil-related sustainability indicators. The soil-related sustainability score is also preferably a score which represents the potential of a field or a sub-field for participating in (especially soil-related) sustainability-related programs or contracts.

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The soil-related sustainability score is more preferably a score which represents the potential of a field or a sub-field zone to sequester carbon. In other words, the soil-related sustainability score is more preferably a technical indicator for the potential of an agricultural field or a sub-field zone to sequester carbon. The soil-related sustainability score is particularly preferably a technical indicator for carbon farming potential of an agricultural field or a sub-field zone.

In another preferred embodiment, the soil-related sustainability score is a technical indicator for soil health of a field or a sub-field zone.

The soil-related sustainability score can be represented as a numeric value, a numeric range, a color code, a vector, an index, a matrix, a bar-code, a QR code, or an identifier. The soil-related sustainability score is preferably a value such as a numeric value, an index, or a matrix. Most preferably, the soil-related sustainability score is a numeric value. Particularly, the soil-related sustainability score is a numeric value from 0 to 100, wherein 0 is the lowest possible score and 100 is the highest possible score.

The soil-related sustainability score is also referred to as “score” in the following.

In the context of the present invention, the term “field” is understood to be any area in which crop plants, are produced, grown, planted, sown, and/or planned to be produced, grown, planted or sown. The term “field” includes agricultural fields, greenhouses, aquacultural fields, horticultural fields, and silvicultural fields. Preferably, field is an agricultural field.

In the context of the present invention, the term “data processing” is understood to be any operation on the data to produce or output meaningful information, which is conducted by a computer system. Data processing includes but is not limited to data search, data validation, data analysis, data aggregation, data sorting, data classification, data summarization, data conversion, data modification, data update etc. Data processing in a database or database system also may include the automated request (including automated search request and automated search) in a database or database system and the automated outputting of the result of such request.

In the context of the present invention, the term “application map” is preferably a map indicating a two-dimensional spatial distribution of the product (used for a treatment) which should be applied or implemented on different locations or zones within a field. In the context of the present invention, the term “sub-field zone” is understood to be a management zone or part of an agricultural field, i.e. an agricultural field can be spatially divided into more than one sub-field zone, wherein each sub-field zone may have different properties such as different crop properties (difference in crop data), different field properties (difference in field data), different soil properties (difference in soil data) – preferably different soil type, soil quality or soil organic matter. Particularly, the application map may indicate that in different sub-field zones, different products or different product dose rates should be applied. For example, the application map may indicate that in the first zone, the product dose rate should be for example 100 liters per hectare, and in a second zone, the product dose rate should be for example 10 liters per hectare.

In the context of the present invention, the time window for a treatment in a field or a sub-field zone can preferably range from 12 months to 1 day, more preferably from 9 months to 1 days, most preferably from 6 months to 2 days, particularly preferably from 3 months to 3 days, particularly more preferably from 2 months to 4 days, particularly from 1 month to 5 days, for example from 2 weeks to 6 days. In the context of the present invention, the time window for a treatment in a field or a sub-field zone can also preferably range from 10 days to 1 hour, more preferably from 7 days to 3 hours, most preferably from 5 days to 5 hours, particularly preferably

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from 3 days to 8 hours, particularly more preferably from 2 days to 12 hours, particularly from 36 hours to 16 hours, for example from 28 hours to 20 hours.

As the spatial variability of the soil data is a source of uncertainty for the generation of the soil-related sustainability model, the measurements of one or more soil data, together or in
 5 combination with a prediction model, can generate predicted soil data, which can be used further in the computer-implemented method of the present invention.

The term “prediction model” as used herein may denote a model that uses mathematical and computational methods to predict an event or outcome. In an example, the prediction model is a
 10 trained computational predictive model, such as a machine learning model, which can be trained using “training data” to recognize patterns, classify data, and forecast future events. Field trials may be conducted to obtain the training data for the machine learning model. In another example, the prediction model is a parametrized mathematical approach that uses an equation-based model to describe the phenomenon of the influence of e.g. the soil data on the
 15 performance of the seed, or on generation of the soil-related sustainability score. The mathematical model is used to forecast an outcome at some future state or time based upon changes to the model inputs. The sample data from field trials may be for example used to fit the parameters of a mathematical equation, which is then used to generate a generation of the soil-related sustainability score from measured soil data.

Such prediction models can also be used in the simulations in (step C).

20 A treatment schedule is a schedule for treating a field or a sub-field zone comprising

- (i) at least one treatment,
 - (ii) at least one time window used for each treatment, and
 - (iii) at least one method and/or product used for each treatment.
- More preferably, a treatment schedule is a schedule comprising:

- 25 (i) at least one treatment,
- (ii) at least one time window used for each treatment, and
- (iii) at least one method, and at least one product used for each treatment.

Most preferably, a treatment schedule is a schedule comprising:

- 30 (i) at least one treatment,
- (ii) at least one time window used for each treatment, and
- (iii) at least one method, and at least one product, and at least one dose rate of the product used for each treatment.

Most preferably, a treatment schedule is a schedule comprising:

- 35 (i) at least one treatment,
- (ii) at least one time window used for each treatment, and
- (iii) at least one method, and at least one product, and at least one application map for applying the product – particularly preferably with different dose rates of the product in different sub-field zones – used for each treatment.

In the context of the present invention, an “agricultural method” or a “method” – in the context of
 40 a treatment – includes but is not limited to

- a) mechanical methods, such as mechanical weed removal or fungi control by machinery such as robots, which for example cuts out the weed or the fungi-infested plant parts, or such as general tillage measures such as ploughing, intertillage, ridging etc.,

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- b) physical methods, such as weed removal or fungi control by optical light (for example laser light),
- c) chemical methods, such as weed removal by applying or spraying a herbicide, or fungi control by applying or spraying a fungicide, or insect control by applying or spraying an insecticide, or nematode control by spraying a nematicide, or attracting beneficial insects to another area outside the agricultural field using chemical attractants, or controlling or improving the soil chemistry, quality or fertility by applying a fertilizer, a nitrification inhibitor, a denitrification inhibitor, or an urease inhibitor, and
- d) biological methods, such as weed removal by applying a microorganism used as bioherbicide for weed removal, or a microorganism used as biofungicide for fungi control, or a microorganism used as bioinsecticide for insect control, or a microorganism used as bionematicide for nematode control, or attracting beneficial insects to another area outside the agricultural field by placing other organisms (which serves as food for the beneficial insects) into this another area, or controlling or improving the soil chemistry, quality or fertility by applying a biological fertilizer, a biological nitrification inhibitor, a biological denitrification inhibitor, or a biological urease inhibitor.

In the context of the present invention, data related to crop data may be

- a) any data which is – e.g. in a database or database system – connected or related to crop data,
- b) any data which can be transformed or translated to crop data,
- c) an identifier or proxy for the crop data, or
- d) crop data as such.

In the context of the present invention, data related to field data may be

- a) any data which is – e.g. in a database or database system – connected or related to field data,
- b) any data which can be transformed or translated to field data,
- c) an identifier or proxy for the field data, or
- d) field data as such.

In the context of the present invention, data related to soil data may be

- a) any data which is – e.g. in a database or database system – connected or related to soil data,
- b) any data which can be transformed or translated to soil data,
- c) an identifier or proxy for the soil data, or
- d) soil data as such.

In the context of the present invention, data related to regulatory data may be

- a) any data which is – e.g. in a database or database system – connected or related to regulatory data,
- b) any data which can be transformed or translated to regulatory data,
- c) an identifier or proxy for the regulatory data, or
- d) regulatory data as such.

In the context of the present invention, data related to treatment schedule may be

- a) any data which is – e.g. in a database or database system – connected or related to a treatment schedule, and/or a time window used for a treatment, and/or a method used for a treatment, and/or a product used for a treatment, and/or a dose rate of a product used for a treatment,
- b) any data which can be transformed or translated to data of a treatment schedule, and/or of a time window used for a treatment, and/or of a method used for a treatment, and/or of a product used for a treatment, and/or of a dose rate of a product used for a treatment (including especially product data).
- c) an identifier or proxy for the data of a treatment schedule, and/or of a time window used for a treatment, and/or of a method used for a treatment, and/or of a product used for a treatment, and/or of a dose rate of a product used for a treatment (including especially product data).
- d) data of a treatment schedule, and/or of a time window used for a treatment, and/or of a method used for a treatment, and/or of a product used for a treatment, and/or of a dose rate of a product used for a treatment as such (including especially product data).

In the context of the present invention, “used for a treatment” includes “useful for a treatment”.

In a preferred embodiment of the present invention, the data processing in (step B2) is carried out in a way to determine or output at least one treatment schedule with the objective of achieving the best possible and most efficient growth of the crop plant, e.g. achieving the highest yield or biomass or crop value or crop quality.

In another preferred embodiment of the present invention, determining the score using the scoring model is carried out in a way to determine or output at least one soil-related sustainability score with the objective of achieving the best accuracy or reliability of the soil-related sustainability score.

In a preferred embodiment of the present invention, the data processing in (step A2) or (step C2) is carried out in a way to determine or output at least one soil-related sustainability score with the objective of achieving the best accuracy or reliability of the soil-related sustainability score.

In another preferred embodiment of the present invention, determining the score using the scoring model is carried out with the following logic: For fields or sub-field zones with a high level of soil organic matter (e.g. approx. > 2 g or 2.5 g per kg soil), the score may be accordingly decreased. For fields or sub-field zones with a low level of soil organic matter (e.g. approx. < 0.5 g or 0.2 g per kg soil), the score may be accordingly increased. For fields or sub-field zones with a better soil type or soil texture (lower soil sandiness or sand content) such as clay or loam, the score may be accordingly increased. For fields or sub-field zones with a worse soil type or soil texture such as sandy soil (higher soil sandiness or sand content), the score may be accordingly decreased. For fields or sub-field zones with a high level of soil moisture, the score may be accordingly increased. For fields or sub-field zones with a low level of soil moisture, the score may be accordingly decreased. For fields or sub-field zones with a low likelihood of drought, the score may be accordingly increased. For fields or sub-field zones with a high likelihood of drought, the score may be accordingly decreased. For fields or sub-field zones with tillage or direct seeding as (soil) pre-treatment, the score may be accordingly increased. For fields or sub-field zones with ploughing as (soil) pre-treatment, the score may be accordingly decreased. Since some specific carbon farming programs do not allow ploughing as (soil) pre-treatment, the score may be accordingly decreased to zero (see also Table 1, “cut-off eligibility”). In case the data regarding the historic or pre-season soil treatment on the field(s) or on the sub-field zone(s)

contains data indicative of the conduction of ploughing, the soil-related sustainability score may more preferably be accordingly decreased to zero.

In another preferred embodiment of the present invention, the data processing in (step A2) or (step C2) is carried out with the following logic: For fields or sub-field zones with a high level of soil organic matter (e.g. approx. > 2 g or 2.5 g per kg soil), the score may be accordingly decreased. For fields or sub-field zones with a low level of soil organic matter (e.g. approx. < 0.5 g or 0.2 g per kg soil), the score may be accordingly increased. For fields or sub-field zones with a better soil type or soil texture (lower soil sandiness or sand content) such as clay or loam, the score may be accordingly increased. For fields or sub-field zones with a worse soil type or soil texture such as sandy soil (higher soil sandiness or sand content), the score may be accordingly decreased. For fields or sub-field zones with a high level of soil moisture, the score may be accordingly increased. For fields or sub-field zones with a low level of soil moisture, the score may be accordingly decreased. For fields or sub-field zones with a low likelihood of drought, the score may be accordingly increased. For fields or sub-field zones with a high likelihood of drought, the score may be accordingly decreased. For fields or sub-field zones with tillage or direct seeding as (soil) pre-treatment, the score may be accordingly increased. For fields or sub-field zones with ploughing as (soil) pre-treatment, the score may be accordingly decreased. Since some specific carbon farming programs do not allow ploughing as (soil) pre-treatment, the score may be accordingly decreased to zero (see also Table 1, "cut-off eligibility"). In case the data regarding the historic or pre-season soil treatment on the field(s) or on the sub-field zone(s) contains data indicative of the conduction of ploughing, the soil-related sustainability score may more preferably be accordingly decreased to zero.

In the the context of the present invention, if the score is between 70 and 90, preferably the following treatment schedules will be outputted:

- treatment schedule containing the growth of cover crops (deeper roots), and/or
- treatment schedule containing broader crop rotation, and/or
- treatment schedule avoiding fallow, and/or
- treatment schedule containing notill soil preparation, and/or
- treatment schedule containing variable rate fertilizer usage and/or use of nitrification inhibitor.

In the the context of the present invention, if the score is between 40 and 60 or between 40 and 70, preferably the following treatment schedules will be outputted

- treatment schedule containing the growth of cover crops (deeper roots), and/or
- treatment schedule containing broader crop rotation, and/or
- treatment schedule avoiding fallow, and/or

- treatment schedule containing notill soil preparation, and/or
- treatment schedule containing variable rate fertilizer usage and/or use of nitrification inhibitor.

In the the context of the present invention, if the score is between 0 and 15 or between 0 and 70, 40, preferably the following treatment schedules will be outputted

- treatment schedule containing the growth of cover crops (deeper roots), and/or

- treatment schedule containing broader crop rotation to include legumes, wheat and canola, and/or

- treatment schedule containing notill soil preparation, and/or
- treatment schedule containing variable rate fertilizer usage and/or use of nitrification inhibitor.

In the context of the present invention, the term “dose rate” is understood as amount of product to be applied per area, for example expressed as liter per hectare (L/ha).

In the context of the present invention, the term “determining” also means “initiating determining”, and the term “generating” also means “initiating generating”.

In the context of the present invention, the term “signal” or “control signal” or “control file” refers to any signal used to provide machine instructions and/or data to a programmable processor.

In the context of the present invention, the term “treatment” or “treat” is understood to be any kind of treatment possible on an agricultural field, including but not limited to seeding, fertilization, crop protection, growth regulation, harvesting, adding or removing of organisms – particularly crop plants – , as well as soil treatment, soil nutrient management, soil nitrogen management, tilling, ploughing, irrigation.

As used herein, the terms “machine-readable medium” and “computer-readable medium” refer to any computer program product, apparatus and/or device (e.g., magnetic discs, optical disks, memory, Programmable Logic Devices (PLDs)) used to provide machine instructions and/or data to a programmable processor, including a machine-readable medium that receives machine instructions as a machine-readable signal.

In the context of the present invention, the term “(by) real-time measurements” preferably means that the corresponding data are directly or indirectly provided by means of an image recognition technology, or by means of remote or proximal sensing of the respective field or sub-field zone. Preferably, crop data are provided by remote or proximal sensing of the respective field or sub-field zone, for example by remote sensing such as remote sensing using satellite imagery.

Preferably, field data are provided by remote or proximal sensing of the respective field or sub-field zone, for example by remote sensing such as remote sensing using satellite imagery. Preferably, **soil data**, particularly data regarding soil organic matter and soil organic carbon content, are directly or indirectly provided by remote or proximal sensing of the respective field or sub-field zone, for example by remote sensing such as remote sensing using satellite imagery.

In the context of the present invention, the term “genetic information” is understood to be any kind of information on the genetic properties of an organism, including but not limited to DNA sequence, RNA sequence, parts of DNA and/or RNA sequences, molecular structure of DNA and/or RNA, epigenetic information (e.g. methylation of DNA parts), information on gene mutations, information on gene copy number variation, information on over-expression of a gene, information on expression level of a gene, information on gene shifting, information on the ratio between wild type and mutants, information on the ratio between different mutants, information on the ratio between mutants and other variants (e.g. epigenetic variants), information on the ratio of different variants (e.g. epigenetic variants).

The simulated soil-related sustainability score is preferably a score which can be potentially achieved in a future time interval t_2 after the treatment would be conducted according to the corresponding treatment schedule. The (normal) soil-related sustainability score is preferably a score which is valid for the current time interval t_1 .

The word “comprising” does not exclude other elements or steps, and the indefinite article “a” or “an” does not exclude a plurality. A single processing means, processor or controller or other

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similar unit may fulfil the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

5 Further, it shall be noted that in the present disclosure, the terms “at least one”, “one or more” or similar expressions indicating that a feature or element may be present once or more than once typically may have been used only once when introducing the respective feature or element. Thus, in some cases unless specifically stated otherwise, when referring to the respective
10 feature or element, the expressions “at least one” or “one or more” may not have been repeated, non-withstanding the fact that the respective feature or element may be present once or more than once.

Further, the terms "preferably", "more preferably", "particularly", "more particularly", "specifically", "more specifically", "optionally" or similar terms are used in conjunction with optional features, without restricting alternative possibilities. Thus, features introduced by these
15 terms are optional features and are not intended to restrict the scope of the claims in any way. The present teachings may, as the skilled person will recognize, be performed by using alternative features. Similarly, features introduced by "according to an aspect" or similar expressions are intended to be optional features, without any restriction regarding alternatives of the present teachings, without any restrictions regarding the scope of the present teachings and
20 without any restriction regarding the possibility of combining the features introduced in such way with other optional or non-optional features of the present teachings.

In the context of the present invention, carbon farming is an agricultural method targeting at sequestering atmospheric carbon into the soil and in crop roots, leaves and other parts of the
25 crop.

In the context of the present invention, the soil-sustainability score may be particularly preferably displayed to the end user in a different way, for example displayed as “high” at the high level of the soil-sustainability score (e.g. value 67 to 100), as “medium” at the medium level of the soil-sustainability score (e.g. value 34 to 66), and as “low” at the low level of the soil-sustainability
30 score (e.g. value 0 to 33).

In the context of the present invention, the score improvement value is the difference between the simulated soil-related sustainability score relating to the at least one treatment schedule and the soil-related sustainability score. The score improvement value is specific for the corresponding treatment schedule.

35 In the context of the present invention, the score improvement value may be particularly preferably displayed to the end user in a different way, for example displayed as high at the high level of the score improvement value (e.g. value greater than +15), as medium at the medium level of the score improvement value (e.g. value +5 to +15), and as “low” at the low level of the score improvement value (e.g. value < +5).

40 The computer-implemented method of the invention can be implemented preferably as an app, which can be used or run on any device, such as mobile devices (mobile phones, smartphones, smartwatches, tablets, notebooks, wearables), computers, control units of agricultural equipment or machines (including tractors, drilling or planting machines, unmanned aerial vehicles).

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In the context of the present invention, the sub-field zones may preferably have an area of approximately 500m x 500m, 200m x 200m, 100m x 100m, 50m x 50m, 20m x 20m, 10m x 10m, 5m x 5m, 2m x 2m, or 1m x 1m (m = metres).

In Table 1, as an example, the generation of the soil-related sustainability score (indicative potential to sequester carbon) of different specific fields or sub-field zones are shown, depending on the following inputs:

- Level of soil organic carbon content (1st column) – as an input of soil data (soil data indicative of the chemical properties of the soil): The score is decreasing with increasing level of soil organic carbon.

- Type of land use (2nd column), for example seeding or planting of annual crops or of perennial crops – as an input of field data, particularly field farming data: In many cases, the score is lower if perennial crops are planted instead of annual crops.

- Soil type (3rd column) – as an input of soil data (soil data indicative of the chemical or physical properties of the soil): The score is decreasing with increasing level of sandiness of the soil, thus, the score is increasing in case of clay and loam as soil types, and decreased in case of sand as soil type.

- Land preparation (4th column) - as an input of field data, particularly field farming data (data regarding direct seeding and/or tillage and/or ploughing treatment of the soil): The score is increasing in case of direct seeding and/or tillage, and is decreasing in case of ploughing. Since some specific carbon farming programs or contracts do not allow ploughing, the score can be decreased to the lowest value of 0, i.e. this field is not eligible for carbon farming programs or contracts (see also 5th column, "cut-off eligibility").

- Cut-off eligibility, meaning eligibility for carbon farming programs or contracts (5th column) – as an input of regulatory data (data regarding the requirements of and/or eligibility for carbon farming programs or contracts): Since some specific carbon farming programs or contracts do not allow ploughing, the score can be decreased to the lowest value of 0, i.e. this field is not eligible for carbon farming programs or contracts.

- High likelihood of drought (6th column) – as an input of field data (field environmental data): The score is decreasing with increasing likelihood of drought, and the score is increasing with decreasing likelihood of drought.

In Table 1, 7th column, the soil-related sustainability score is outputted as range of numeric values, ranging from 0 (lowest) to 100 (highest).

In Table 1, 8th column, recommended treatment schedules are shown, which would typically result in an appropriate or good score improvement value (if generated according to this invention).

In Table 2, as an example, the generation of the soil-related sustainability score and of the score improvement value is shown for the three fields (or sub-field zones) A, B, and C. The initial score is 60 (field A), 70 (field B) and 80 (field C). Then, treatment schedules T1 or T2 are generated either according to the present invention or provided for example by the user. T1 includes the application of a specific fungicide during a specific time window (e.g. within the next 3 weeks). T2 includes the application of a specific nitrification inhibitor during a specific time window (e.g.

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within the next 3 weeks). The simulated score generated according to the present invention in case of conducting the treatment according to treatment schedule T1 is 70 (field A), 79 (field B) and 80 (field C). The simulated score generated according to the present invention in case of conducting the treatment according to treatment schedule T2 is 75 (field A), 72 (field B) and 80 (field C). For example, regarding the generation of the simulated score for treatment schedule T2, in (step C2), the soil data, e.g. the nitrogen content is for example modified (in case increased for field A and slightly increased for field B) in the simulation under the assumption that treatment schedule T2 will be conducted. Thus, the score improvement value for treatment schedule T1 is +10 (field A), +9 (field B) and +0 (field C). The score improvement value for treatment schedule T2 is +15 (field A), +2 (field B) and +0 (field C). If a ranking of the treatment schedules according to score improvement value would be done according to the present invention, treatment schedule T2 would be ranked higher than T1 for the field A, and treatment schedule T1 would be ranked higher than T2 for the field B. Therefore, in this case, a control signal will be outputted to the agricultural machine to start treatment according to the treatment schedule T2 for field A, and a further control signal will be outputted to the agricultural machine to start treatment according to the treatment schedule T1 for field B.

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Examples

Table 1: Example for the generation of soil-related sustainability score

Input	Land Use	Soil Type	Land preparation	Cut-off Eligibility (Based on general requirements of carbon farming programs)	High likelihood of drought	Soil-related sustainability score (Indicative score potential to sequester carbon)	Recommendation
Soil organic carbon low level	Annual Crops	Clay	Conservation Tillage	YES	yes	40 to 50	
	Annual Crops	Clay	Conservation Tillage	YES	no	70 to 90	High potential for carbon farming. Soil Health: Implement cover crops (deeper roots), broader crop rotation, avoid fallow and implement no till soil preparation. Please consider variable rate fertilizer and use of nitrification inhibitor.
	Annual Crops	Clay	Ploughing	NO		0	
	Annual Crops	Clay	Direct Seeding	YES	yes	50 to 60	
	Annual Crops	Clay	Direct Seeding	YES	no	80 to 100	
	Annual Crops	Clay	Conservation Tillage	YES	yes	30 to 50	
	Annual Crops	Clay	Conservation Tillage	YES	no	50 to 70	
	Annual Crops	Loam	Ploughing	NO		0	
	Annual Crops	Loam	Direct Seeding	YES	yes	20 to 40	
	Annual Crops	Loam	Direct Seeding	YES	no	40 to 60	Medium to high potential for carbon farming. Soil Health: Consider cover crops (deeper roots) and avoid fallow, broader rotation and no till soil preparation. Please consider variable rate fertilizer and use of nitrification inhibitor.
	Annual Crops	Loam	Conservation Tillage	YES	yes	1 to 10	
	Annual Crops	Loam	Conservation Tillage	YES	yes		

	Annual Crops	Loam	Conservation Tillage	YES	no	5 to 15	
	Annual Crops	Sand	Ploughing	NO		0	
	Annual Crops	Sand	Direct Seeding	YES	yes	1 to 10	Not appropriate for carbon farming. For soil health, continue no till, cover crops, expand crop rotation to include legumes, wheat and canola. Please consider variable rate fertilizer and use of nitrification inhibitor.
	Annual Crops	Sand	Direct Seeding	YES	no	5 to 15	Not appropriate for carbon farming. For soil health, continue no till, cover crops, expand crop rotation to include legumes, wheat and canola. Please consider variable rate fertilizer and use of nitrification inhibitor.

Table 2: Further examples for the generation of soil-related sustainability score and the score improvement value.

	Field / zone A	Field / zone B	Field / zone C
(Initial) Score	60	70	80
Simulated score under simulation of conducting treatment schedule T1 (fungicide application)	70	79	80
Simulated score under simulation of conducting treatment schedule T2 (nitrification inhibitor application)	75	72	80
Score improvement value for T1	+10	+9	+0
Score improvement value for T2	+15	+2	+0
Optionally: Control signal to the machine	Start treatment according to T2	Start treatment according to T1	No treatment

Figure 1 illustrates the workflow of the embodiment of the present invention:

In block 102, routine 100 (step A1) receives by the computing unit – from a database and/or from user input and/or from real-time measurements – crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s), and field data relating to the field(s) or sub-field zone(s), and soil data relating to the field(s) or sub-field zone(s), and optionally regulatory data relating to the field(s) or the sub-field zone(s). In block 104, routine 100 (step A2) at least based on the crop data, and the field data, and the soil data, generates a soil-related sustainability score for a field or a sub-field zone using a scoring model, wherein the scoring model is dependent on the following parameter groups:

(PG1) crop parameter(s),

(PG2) soil-carbon parameter(s), and/or soil-physical parameter(s), and

(PG3) field environment parameter(s), and/or field farming parameter(s).

In block 106, routine 100 (step A3) determines at least one treatment schedule based on the generated soil-related sustainability score. In an optional block 108, routine 100 (step A4) – based on the at least one determined treatment schedule – outputs a control file usable for controlling an agricultural equipment which can be used to treat the agricultural field. Routine 100 is preferably the system (e.g. an app) in which the computer-implemented method according to the present invention is implemented.

Figure 2

Figure 2 illustrates an embodiment of the data flow of the computer-implemented method of the present invention.

In a first data flow section, which corresponds to the (step A1) or (step A1') of the computer-implemented method of the present invention, data sources 101 are made available, wherein the data sources can be for example user device 103, database 105 and/or sensor 107. The term “user input device” is understood to be a computer, a smartphone, a tablet, a smartwatch, a monitor, a data storage device, or any other device, by which a user, including humans and robots, can input or transfer data to the field management system 112. The term “input database” is understood to be any organized collection of data, which can be stored and accessed electronically from a computer system, and from which data can be inputted or transferred to the field management system 112. The term “sensor” is understood to be any kind of physical or virtual device, module or machine capable of detecting or receiving real-world information and sending this real-world information to another system, including temperature sensor, humidity sensor, moisture sensor, pH sensor, pressure sensor, soil sensor, crop sensor, water sensor, and cameras.

In a further data flow section, data which originated from one of the data sources 101 are optionally preprocessed in the data preprocessing section 110, wherein such data preprocessing may include data calibration, data transformation (e.g. into a different format), data correction, data validation, and data verification.

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In a further data flow section, the data which originated from one of the data sources 101 and which has been optionally preprocessed in the data preprocessing section 110 are inputted into the field management system 112, for example as crop data 122, as field data 124, as (optional) regulatory data 126, soil data 128, or as weather data 130.

In a further data flow section, which corresponds to the (step A2)/(step A2') and/or the (step A3) of the computer-implemented method of the present invention, the above mentioned data are processed by the field management system in the data processing section 120 using for example one or more crop-related models 142, one or more field-related models 144, one or more scoring models 146, one or more soil-related models 148, one or more weather models 150, or a combination of such models. Crop-related model 142 is an algorithm which is capable of determining, predicting and/or simulating crop species, crop phenology, crop growth, crop development and other crop related properties based on specific input data. Field-/soil-related model 144 is an algorithm which is capable of determining, predicting and/or simulating soil properties of a field, field farming parameters, field environmental parameters, or other field related properties based on specific input data. Scoring model 146, which is the core element of the present invention, is an algorithm which is capable of determining the soil-related sustainability score based on specific input data (especially crop data, field data, soil data). Agronomic recommendation model 148 is an algorithm which is capable of determining one or more methods, products (particularly fertilizers and/or nitrification inhibitors and/or urease inhibitors), dosages, time windows, or other treatment parameters for achieving a specific real-world agronomic objective, particularly fertilizing, based on specific input data, especially based on the determined soil-related sustainability score. Weather model 150 is an algorithm which is capable of determining, predicting and/or simulating any weather-related parameters including its development, such as temperature, precipitation, moisture, humidity, sunshine, or wind speed. Within the data processing section 120, the output of one of the above mentioned model may also be directly used as input of another of the above mentioned models. Within the data processing section 120, at least two, preferably at least three, more preferably at least five of the above mentioned models may also be run either in a parallel arrangement or in a sequential arrangement or in a combination of parallel and sequential arrangement. For example, the treatment schedule is determined based on applying the agronomic recommendation model to the determined soil-related sustainability score.

In a further data flow section, which corresponds to the (step A4) or (step A3') of the computer-implemented method of the present invention, the final outputs of the model(s) in the data processing section 120 are transferred from the field management system to the data output layer 160 and for example outputted on a user device 162, in an output database 164 or as a control file 166. The term "user output device" is understood to be a computer, a smartphone, a tablet, a smartwatch, a monitor, a data storage device, or any other device, by which a user, including humans and robots, can receive data from the field management system 112. The term "output database" is understood to be any organized collection of data, which can be stored and accessed electronically from a computer system, and which can receive data which is outputted or transferred from the field management system 112. The term "control file" is understood to be any binary file, data, signal, identifier, code, image, or any other machine-readable or machine-detectable element useful for controlling a machine or device, for example an agricultural treatment device.

Figure 3

Figure 3 schematically illustrates a treatment management system 500. The treatment parameters determined by the computer-implemented method of the present invention will be outputted or further processed as a control signal for an agricultural equipment embedded in the treatment management system 500, wherein the agricultural equipment is preferably a fertilizer application device, a sprayer or a seed drill or planter (e.g. for planting cover crops). The treatment management system 500 may comprise a fertilizer application device, a sprayer, a seed drill or planter 510, a data management system 520, a field management system 112, and a client computer 540. The a fertilizer application device 510 may be e.g. ground robots with variable-rate applicators, or other variable-rate applicators for applying seed products or fertilizers to the field 502.

In the example of Figure 3, the fertilizer application device / sprayer / seed drill / planter 510 is embodied as smart farming machinery. The smart farming machinery 510 may be a smart fertilizer application device / smart sprayer / smart seed drill / smart planter and includes a connectivity system 512. The connectivity system 512 may be configured to communicatively couple the smart farming machinery 510 to the distributed computing environment. It may be configured to provide data collected on the smart farming machinery 510 to the data management system 520, the field management system 112, and/or the client computer 540 of the distributed computing environment.

The data management system 520 may be configured to send data to the smart farming machinery 510 or to receive data from the smart farming machinery 510. For instance, as detected maps or as applied maps comprising data recorded during application on the field 502 may be sent from the smart farming machinery 510 to the data management system 520. For instance, the data management system 520 may comprise georeferenced data of different fields and the associated treatment map(s).

The field management system 520 may be configured to provide a control protocol, an activation code or a decision logic to the smart farming machinery 510 or to receive data from the smart farming machinery 510. Such data may also be received through the data management system 520.

The field computer 540 may be configured to receive a user input and to provide a field identifier and an optional treatment specifier to the field management system 112. Alternatively, the field identifier may be provided by the fertilizer application device / sprayer / seed drill / planter 510. Alternatively, the optional treatment specifier may be determined using e.g. growth stage models, weather modelling, neighbouring field incidences, etc. The field management system 112 may search the corresponding agricultural field and the associated treatment map(s) in the data management system 520 based on the field identifier and the optional treatment specifier. The field computer 540 may be further configured to receive client data from the field management system 112 and/or the smart farming machinery 510. Such client data may include for instance application schedule to be conducted on certain fields with the smart farming machinery 510 or field analysis data to provide insights into the health state of certain fields.

The treatment device 510, the data management system 520, the field management system 112, and the client computer 540 may be associated with a network. For example, the network may be the internet. The network may alternatively be any other type and number of networks. For example, the network may be implemented by several local area networks connected to a

wide area network. The network may comprise any combination of wired networks, wireless networks, wide area networks, local area networks, etc.

The data processing system of the present invention may be embodied as, or in, or as part of the field management system 112 to perform the above-described method to provide a control data to the smart farming machinery 510. For example, the field management system 112 may receive the fertilizer application device configuration data from the fertilizer application device / sprayer / seed drill / planter 510 via the connectivity system 512. The field management system 112 may receive geo-dependent environmental data (e.g. temperature, moisture, humidity, and/or wind speed) from one or more sensors installed on the fertilizer application device / sprayer / seed drill / planter 510 to monitor environmental data. Alternatively or additionally, the field management system 112 may receive geo-dependent environmental data from weather services.

Claims:

1. A computer-implemented method for determining a treatment schedule for treating an agricultural field, comprising the following steps:
 - (step A1) receiving by the computing unit – from a database and/or from user input and/or from real-time measurements –
 - crop data relating to the crop(s) planted or to be planted in the field(s) or sub-field zone(s) and indicative of at least one crop parameter, and
 - field data relating to the field(s) or sub-field zone(s) and indicative of at least one field environment parameter and/or field farming parameter, and
 - soil data relating to the field(s) or sub-field zone(s) and indicative of at least one soil-carbon parameters and/or soil-physical parameter,
 - optionally regulatory data relating to the field(s) or the sub-field zone(s),
 - (step A2) at least based on the crop data, and the field data, and the soil data, generating a soil-related sustainability score for a field or a sub-field zone using a scoring model, wherein the scoring model is dependent on the following parameter groups:
 - (PG1) crop parameter(s),
 - (PG2) soil-carbon parameter(s), and/or soil-physical parameter(s), and
 - (PG3) field environment parameter(s), and/or field farming parameter(s),
 - (step A3) determining at least one treatment schedule based on the generated soil-related sustainability score.
2. Computer-implemented method according to claim 1, further comprising (step A4) based on the determined treatment schedule, outputting a control file usable for controlling an agricultural equipment which can be used to treat the agricultural field.
3. Computer-implemented method according to claim 1, wherein the soil data are indicative of at least one soil-carbon parameter and at least one soil-physical parameter, and wherein the scoring model is dependent on the following parameter groups:
 - (PG1) crop parameter(s),
 - (PG2) soil-carbon parameter(s), and soil-physical parameter(s),
 - (PG3) field environment parameter(s), and/or field farming parameter(s).
4. Computer-implemented method according to claim 1, wherein the field data are indicative of at least one field environment parameter and at least one field farming parameter, and wherein the scoring model is dependent on the following parameter groups:
 - (PG1) crop parameter(s),
 - (PG2) soil-carbon parameter(s), and/or soil-physical parameter(s),
 - (PG3) field environment parameter(s), and field farming parameter(s).
5. Computer-implemented method according to claim 1, wherein the soil data are indicative of at least one soil-carbon parameter and at least one soil-physical parameter, and wherein the field data are indicative of at least one field environment parameter and at least one field farming parameter, and wherein the scoring model is dependent on the following parameter groups:
 - (PG1) crop parameter(s),
 - (PG2) soil-carbon parameter(s), and soil-physical parameter(s),
 - (PG3) field environment parameter(s), and field farming parameter(s).
6. Computer-implemented method according to anyone of the preceding claims, wherein the soil-carbon parameter is soil organic matter concentration, soil organic matter stock,

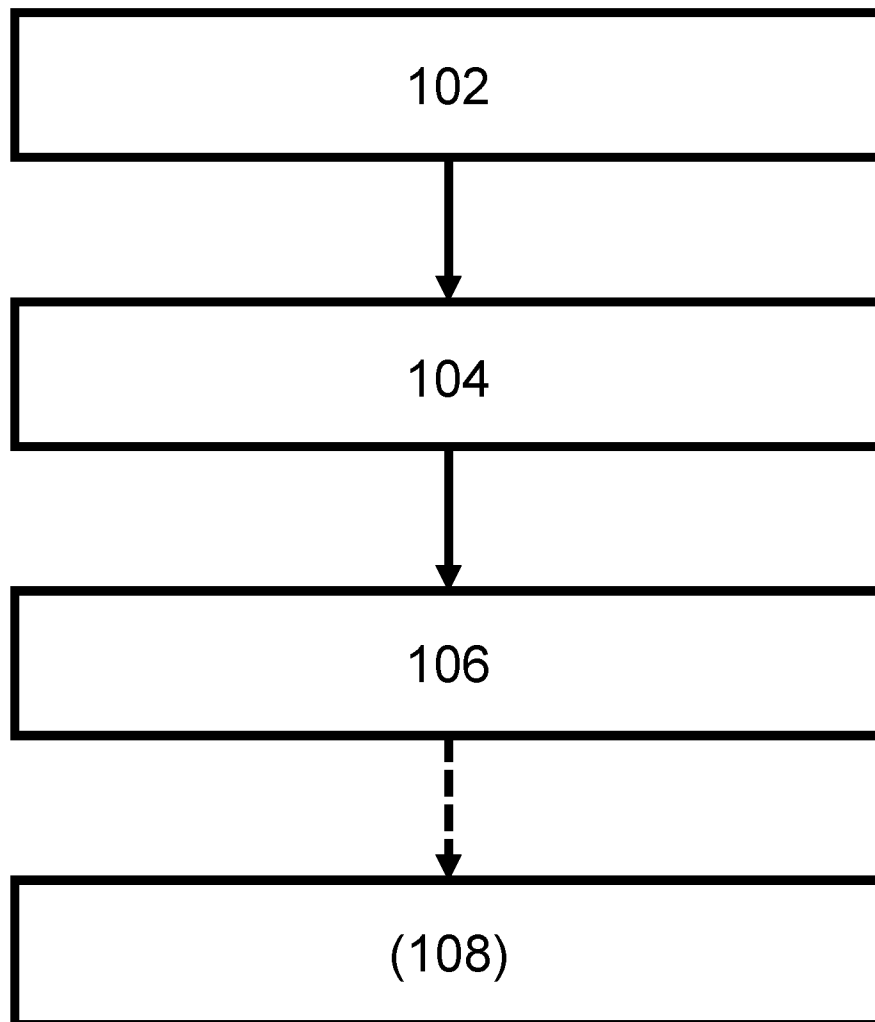
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soil organic carbon concentration, soil organic carbon stock, total carbon concentration, and/or total carbon stock of the soil in the field(s) or sub-field zone(s).

7. Computer-implemented method according to anyone of the preceding claims, wherein the soil-physical parameter is soil type, soil quality, soil sandiness, soil moisture, soil humidity, soil temperature, soil surface temperature, soil texture, soil taxonomy, soil texture class, soil conductivity, soil fertility, soil pH value, and/or the water holding capacity of the soil in the field(s) or sub-field zone(s).
8. Computer-implemented method according to anyone of the preceding claims, wherein the field environment parameter is climate status and/or condition, weather status and/or condition, temperature, air temperature, soil temperature, soil surface temperature, canopy temperature, humidity, air humidity, relative humidity, precipitation, moisture, wind condition, wind speed, sunlight level, likelihood of drought, likelihood of floods, or likelihood of extreme weather conditions relating to the field(s) or sub-field zone(s).
9. Computer-implemented method according to anyone of the preceding claims, wherein the field farming parameter is the application of crop protection or crop nutrition products on the field(s) or on the sub-field zone(s) in the past, growth of plants on the field(s) or on the sub-field zone(s) in the past, pre-season soil treatment on the field(s) or on the sub-field zone(s), historic or current land use, soil conservation practices – including the degree or extent of direct seeding and/or tillage and/or ploughing treatment – of the soil, the type of cultivation of the field(s) or sub-field zone(s).
10. Computer-implemented method according to anyone of the preceding claims, wherein the crop parameter is
 - a) crop species or variety of the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), preferably including genetic information of such crop, and/or
 - b) crop value of the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), preferably including oil content, protein content, and/or nutrient content of such crop, and/or
 - c) crop growth relating to the at least one crop planted or to be planted in the field(s) or in the sub-field zone(s), preferably including days to sexual maturity, vigor, emergence rating of such crop, growth stage (e.g. BBCH) of a crop, and/or
 - d) type of crops to be planted on the field(s) or on the sub-field zone(s), wherein the type of crops is either an annual crop or a perennial crop, and/or
 - e) the growth or non-growth of cover crops on the field(s) or on the sub-field zone(s).
11. Computer-implemented method according to anyone of the preceding claims, wherein
 - the crop parameter is the growth or non-growth of cover crops on the field(s) or on the sub-field zone(s), and/or
 - the soil-carbon parameter is the soil organic carbon content of the soil in the field(s) or sub-field zone(s), and/or
 - the soil-physical parameter is the soil type or soil texture of the soil in the field(s) or sub-field zone(s), and/or
 - the field environment parameter is the likelihood of drought relating to the field(s) or sub-field zone(s), and/or
 - the field farming parameter is the soil conservation practice – including the degree or extent of direct seeding and/or tillage and/or ploughing treatment – of the soil.

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12. Computer-implemented method according to anyone of the preceding claims, wherein the regulatory data relating to the field(s) or sub-field zone(s) include:
data regarding the requirements of and/or eligibility for carbon farming programs or contracts, data regarding the methodologies of carbon farming programs or contracts, data regarding the legal framework for carbon farming in specific countries, data regarding the requirements of and/or eligibility for sustainability programs or contracts, data regarding the methodologies of sustainability programs or contracts, data regarding the legal framework for sustainability programs or contracts in specific countries, data regarding the requirements of and/or eligibility for organic farming programs or contracts, data regarding the methodologies of organic farming programs or contracts, data regarding the legal framework for organic farming in specific countries, data regarding the requirements of and/or eligibility for climate smart farming programs or contracts, data regarding the methodologies of climate smart farming programs or contracts, data regarding the legal framework for climate smart farming in specific countries, data regarding the requirements of and/or eligibility for regenerative farming programs or contracts, data regarding the methodologies of regenerative farming programs or contracts, data regarding the legal framework of regenerative farming in specific countries, data regarding the requirements and/or eligibility for agroecology programs or contracts, data regarding the methodologies of agroecology programs or contracts, data regarding the legal framework of agroecology in specific countries, data regarding the requirements of and/or eligibility for agroforestry programs or contracts, data regarding the methodologies of agroforestry programs or contracts, data regarding the legal framework of agroforestry in specific countries, data regarding the requirements of and/or eligibility for integrated farming programs, data regarding the methodologies of integrated farming programs, and/or data regarding the legal framework of integrated farming in specific countries.
13. A data processing system comprising means for carrying out the computer-implemented method according to anyone of the claims 1 to 12.
14. A computer program product comprising instructions which, when the program is executed by a computer, cause the computer to carry out the computer-implemented method according to anyone of the claims 1 to 12.
15. A computer-readable storage medium comprising instructions which, when executed by a computer, cause the computer to carry out the computer-implemented method according to anyone of the claims 1 to 12.

Fig. 1100

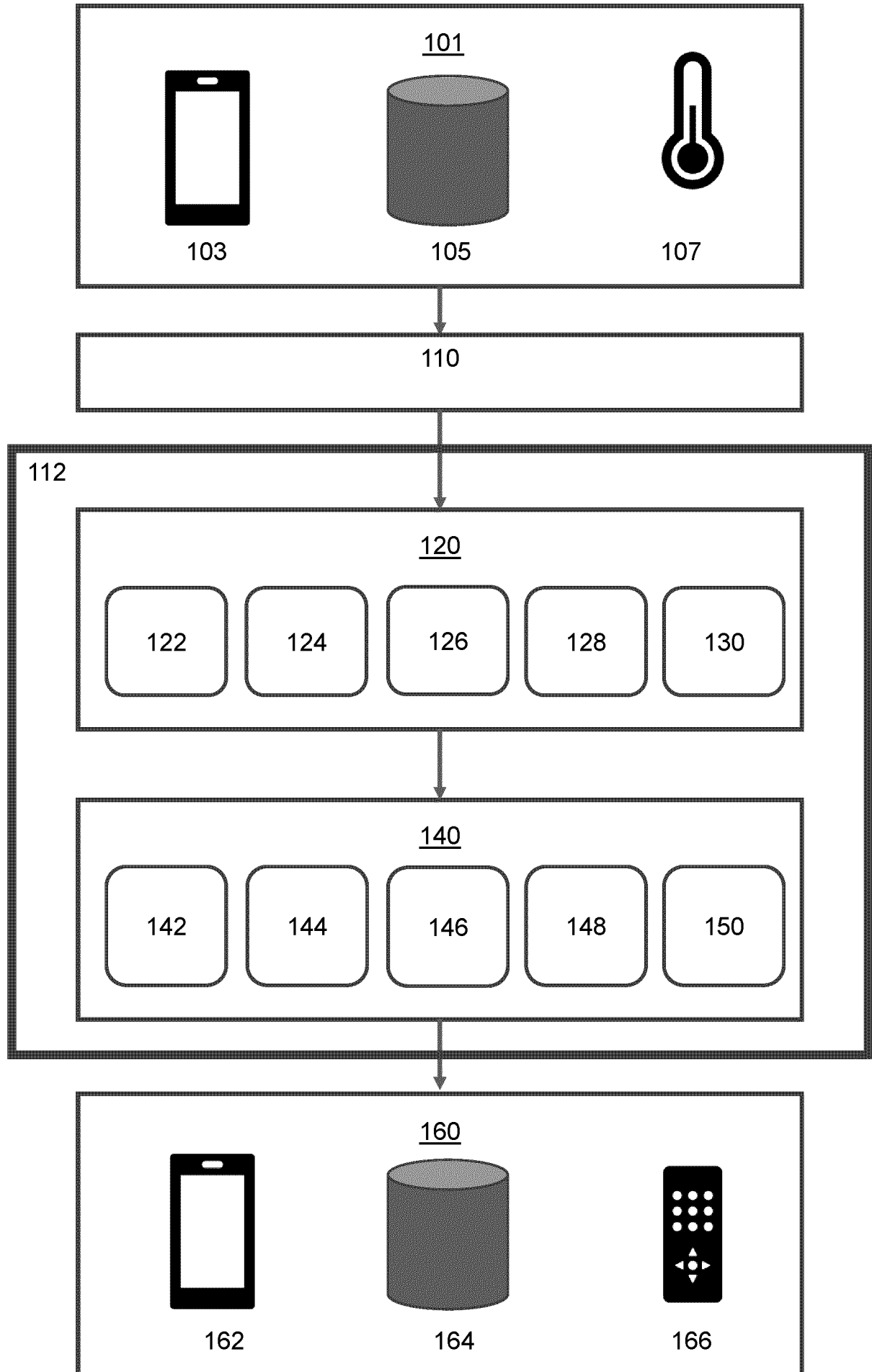
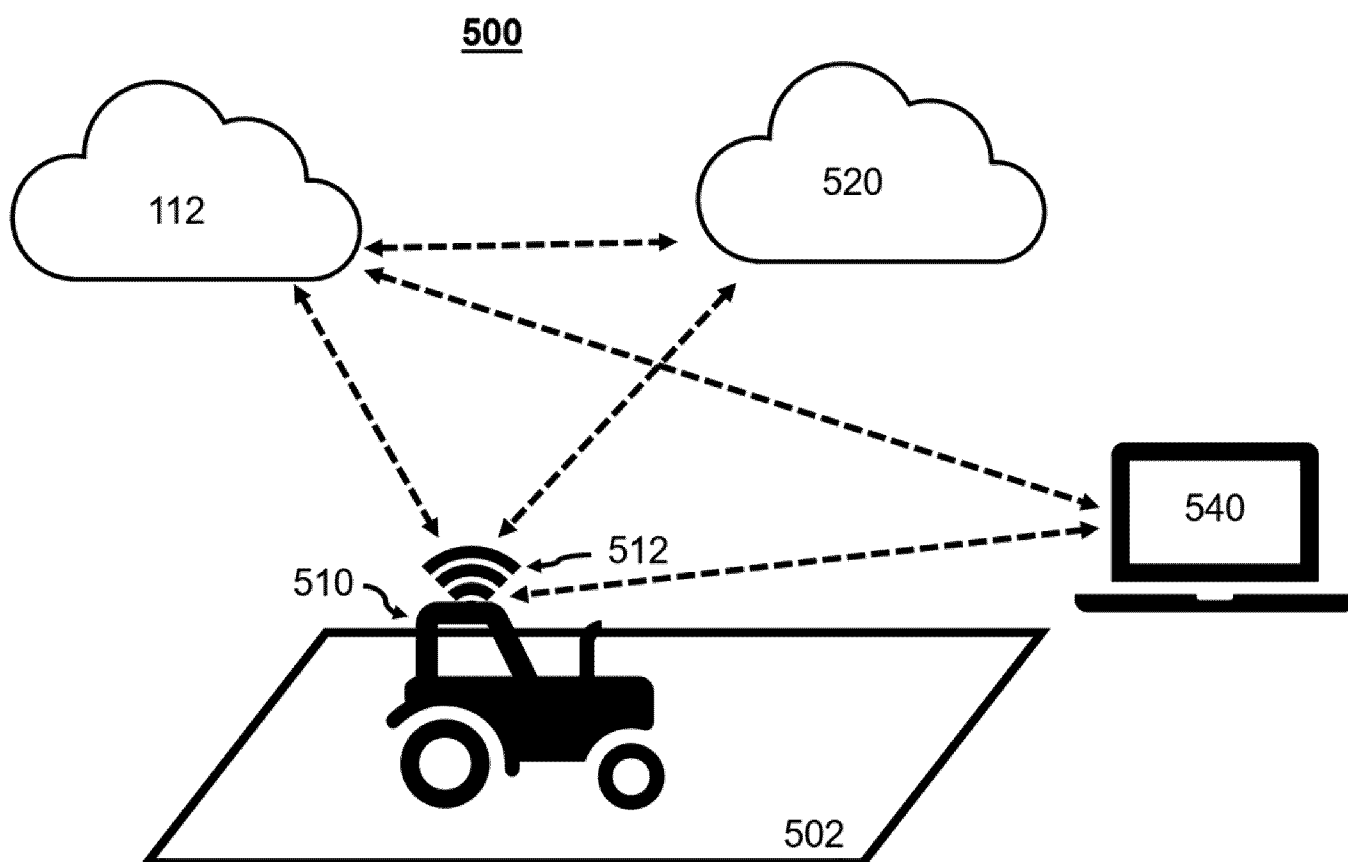
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Fig. 2

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2022/057986

A. CLASSIFICATION OF SUBJECT MATTER INV. G06Q50/02 G06Q10/06 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) G06Q		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2019/335674 A1 (BASSO BRUNO [US]) 7 November 2019 (2019-11-07) abstract; figures 1, 8 paragraphs [0021] - [0034] paragraphs [0057], [0072] - [0098] paragraphs [0121] - [0129] -----	1-15
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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents :		
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 20 July 2022		Date of mailing of the international search report 29/07/2022
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Mülthaler, Evelyn

INTERNATIONAL SEARCH REPORT

International application No

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