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TITLE: Benchmarking and Performance Indicator Monitoring Tools

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Benchmarking and Performance Indicator Monitoring Tools

1 Summary

DEMETER aims to lead the Digital Transformation of the European Agrifood sector based on the rapid adoption of advanced technologies, such as Internet of Things, Artificial Intelligence, Big Data, Decision Support (DSS), Benchmarking, Earth Observation, etc., to increase performance in multiple aspects of farming operations, as well as to ensure the long-term viability and sustainability of the sector. It aims to put these digital technologies at the service of farmers using a human-in-the-loop approach that constantly focuses on mixing human knowledge and expertise with digital information.

The Benchmarking and Performance Indicator Monitoring Tools (hereafter Benchmarking) aim to provide end-users with tools to evaluate the productivity and the sustainability of the practices adopted, as well as the efficacy of the developed digital solutions. The benchmarking components will enable the comparison for individual and peer to peer learning, linked to the impact of operational processes brought by DEMETER.

2 Benchmarking And Performance Indicator Monitoring Tools

To provide a benchmarking system that can be used by all the pilots, a minimum set of indicators covering pilots' activities has been established and constraints relating to data availability at the farm level have been addressed. Based on these indicators, the Benchmark tools will provide feedback about the agronomic, environmental, and economic sustainability of the practices adopted and of the technologies delivered within DEMETER. The benchmark system will allow the comparison of farms through three different components: i) generic economic farm comparison (exploiting the data of FADN[1]), ii) neighbouring benchmarking (a group of farms with similar environmental conditions and type of farming), and iii) technology benchmarking (to evaluate the impact of a specific technology).

[1] Farm Accountancy Data Network (FADN) monitors farms' income and business activities.

2.1 Indicators

A critical starting point for developing assessment methods is the selection of representative indicators being sufficiently comprehensive to be applicable in different geographic locations, while sufficiently sensitive to different impacts, crops, and production methods. The aim of the benchmarking system is to create a framework to manage a complex set of indicators able to meet the needs of the pilots in evaluating the achievement of objectives and the success in applying DEMETER technologies.

Hence, the selection process assessed indicators which should be available and measurable for most of the pilots. The data required for indicator measurements should be gathered at the farm/field level, considering data made available by devices, automatically recorded, or provided as output by models.

Keeping in mind the DEMETER project objectives, the indicators selected for assessing performance sustainability cover the following three main sectors:

- Agronomic (quantity and quality of the production, and the use of input).
- Environmental (biodiversity, environmental efficiency, and impact).
- Economic (farm profit and technical efficiency).

Each sector has been further divided into sub-sectors, and for each of these, the set of indicators has been kept to a minimum, to facilitate the application to the pilots which are focusing on different aspects of the agricultural domain and to meet the constraints of data availability at farm/pilot level.

The process of indicators definition and calculation does not end here, as the benchmarking framework will allow users to extend the current indicators list according to their needs, objectives, and data availability. The selected indicators are calculated yearly since the benchmarking components allow the comparison of the indicators on a yearly basis.

2.1.1 Agronomic Indicators

Agronomic indicators aim to assess crucial elements of agricultural production: farm size, yield (levels, variability in time and space), yield quality, input use and animal wellbeing. The yield benchmarking is of particular interest for farmers and advisors since it may provide evidence of the possible improvements that can be obtained in yield or the gap that can be filled if adequate management decisions are undertaken, or if a new technology is applied. The agronomic sector consists of the following sub-sectors:

- Structural: the farm structure in terms of activities, size, and morphology.
- Yield – Crop: a crop's quantitative parameters in terms of productivity.
- Yield – Livestock: livestock's quantitative parameters.
- Yield - Crop quality: some simple quality parameters of the crops.
- Yield - Livestock quality: some simple parameters for quality of livestock.
- Animal welfare: behavioural, physical, physiological and production features.
- Crop input - external resources and promoting the monitoring of input.

2.1.2 Environmental Indicators

This first list of environmental indicators has been collected with the aim of addressing relevant sustainability aspects and describing environmental concerns for agricultural production processes. Principal aspects taken into account have been farm biodiversity, the use of water for irrigation, the nutrient management, the use of agrochemicals in pest management:

- Farm biodiversity: the biological variety and variability within the farm. Biodiversity is a critical resource, and it is typically measured in terms of variation at different levels: genetic, species, ecosystem, or landscape.
- Water Environmental Efficiency: environmental impact and efficiency of farm inputs and how these contribute to the production and habitat conservation.
- Nutrient Environmental Efficiency: environmental impact and efficiency of farm inputs and explores how these contribute to the production and habitat conservation. Here, we focus on nitrogen use efficiency.
- Pesticide Environmental Efficiency: the environmental impact and efficiency of farm inputs and their contribution to production and habitat conservation.
- Erosion: assesses the risk of soil erosion by abiotic factors. This gives a useful picture of soil health through the assessment of land degradation.

2.1.3 Economic Indicators

The indicators of this sector were selected following some key concepts of farm business analysis: profit, technical efficiency, and economic efficiency. The following sub sectors have been identified:

- Farm balance: includes indicators of costs and incomes related to the whole farm, independently from the activities that have generated them. These indicators are very relevant to the farmers for the evaluation of the economic performance of the whole farm activity.
- Crop balance: includes the specific income and costs derived from land cultivation. These indicators inform farmers about the whole crop

production sector performance, as well as the economic performance of the main crops.

- Livestock balance: these indicators support farmers in the control of specific incomes and costs derived from the breeding activities. This can help inform farmers about the whole breeding sector performance.
- Input economic efficiency (water): indicators of economic efficiency of inputs allow to estimate the effectiveness of the input use in the farm practice. In an era of water scarcity, the knowledge of the efficiency of the single water unit may be of great help to the farmers to optimise their irrigation strategy.
- Input economic efficiency (nutrients): economic efficiency of inputs can be measured also for nutrients. The knowledge of the efficiency of the single fertiliser unit, and of its incidence on the total crop production costs, may be of great help to the farmers to optimise their fertilisation strategy.
- Labour: labour represents an important cost item for farmers and includes efficiency indicators, which can help farmers to control the labour costs and its efficiency for different activities.
- Machineries: machinery economic indicators help farmers to control the costs for machinery, analysing their incidence on the total costs.

2.2 Benchmarking Components

The benchmarking system is based on four components which are described in the following sections. All the components have been integrated into the same package making it easier to install and allowing the same indicators to be used for multiple activities.

In addition to the main benchmarking API and data analysis tool, the package contains the following open-source products:

- db: is a database based on the PostgreSQL relational database coupled with PostGIS, which adds support for geographic objects.
- pgadmin: the database web interface for maintenance and direct access for reporting and advanced analysis.
- nginx: the web server proxy.

2.2.1 Component 4.I.0: Indicator Engine for Benchmarking Purpose

The Indicator Engine manages the indicators to assess the current agronomic, economic, and environmental sustainability with data available at the farm level allowing it to:

- Publish and keep track of the list of indicators.
- Allow pilots integrators to update and extend the list of the indicators.

- Store the results of the indicators if the values are needed for benchmarking.

The main data element is the indicator, *KpiIndicator*, which describes a specific indicator belonging to a specific sector.

2.2.2 Component 4.I.1: Generic Farm Comparison

The Generic Farm Benchmarking component provides each farm with a set of basic economic indicators, which can be used as a general benchmark of farm activities. The system is based on the Farm Accountancy Data Network (FADN) database to provide a set of reference values to be used to benchmark the farm activities with a set of similar farms belonging to the FADN network. For this analysis, a schema has been created in the Benchmarking database containing the following datasets:

- Spatial reference of the European Administrative division; the geometry allows the extraction of the administrative division and the relative average data from the FADN.
- FADN data extracted from the FADN website.

The benchmarking algorithm is based on the following steps:

- Acquisition of farm data definition in the AIM data format.
- Extraction of farm location and search of the correspondent FADN regions.
- Extraction from the farm data of a set of basic structural indicators, which provide a generic description of the farm dimensions and typology.
- Search, within the region, for the “closest” combination of Size and Typology using a multidimensional-distance algorithm to find the closest combination.
- Extract a sub-set of indicators for the last 10 years; the global parameters (e.g., total input and output) will allow farmers to compare their performance with the average of similar farms in the same area.

A minimal set of easily available data has been defined allowing the farm to get an estimated reference of the economic farm performance indicators: expected output, expected input and expected profit, along with an estimation of the input and output division in general areas. The system does not ask farmers to share the actual farm economic data, the component shows only the reference values, and so does not require sensitive information about the farm. The inputs needed are:

- Location of the main farm centre: the administrative division of the farm centre (NUTS3) can be used if they do not want to share the geographic location.
- Farm structure:

- Average surface of the main crop groups (or all the plot geometries).
- Number of standard livestock units (LSU) by species.

The component output is a set of *KpiIndicator* and its comparative relative *KpiIndicator*. Through the interface the user can access the data for the most recent available years:

- Access a set of indicators; if actual farm data is provided the status shows the differences.
- It is possible to move across years and access historical data to assess the variation in time of the indicators.
- The system shows how the total input and output are divided in sub-categories.

2.2.3 Component 4.I.2: Neighbour Benchmarking

This allows a group of farms to share data and compare performance. The methodology to create a neighbour benchmarking tool is as follows:

- Group Creation: A group coordinator can create groups in the system; the creator is the owner of the group, and a group has the following features:
  - Group name.
  - Mode: the group can be open (all valid users can push their own data) or closed (only a set of users can participate at the benchmarking).
  - Users: an array of the email of the participants (if the group is closed).
  - Indicators: an array of the indicators associated with that group; if the array is empty all the system indicators can be collected.
  - Reference method: the coordinator can choose how the reference value will be calculated from the following options:
    - Average: average of the group values; default value.
    - Median: median of the group values.
    - Top 25 percentile: top 25 percentiles.
- Farm association: a user with the valid credential can associate the farm with the group; the system checks and accepts the request; the system produces a guide for that specific farm allowing data entry and the benchmarking.
- Data entry: the user can add a new set of indicators to the farm space. The system has an UPSERT method of data entry meaning that if an indicator value already exists for that farm, it will update the current value.
- Benchmarking: the farm can use their specific URL to get the result of the indicators showing how it performs compared to other farms in the group.

2.2.4 Component 4.I.3: Technology Benchmarking

This component has two potential uses:

- to allow a farmer or a group of farmers to evaluate the performance of a technology from the agronomic, economic, and environmental point of view.
- as a benchmarking mechanism for DEMETER technology, based on data collected by the farms of the several pilots to validate the achievement of the DEMETER project KPIs.

The methodology to create benchmarking for a specific technology is as follows:

- Technology creation: a coordinator should create a new entry in the benchmarking system, allowing a group of farmers to enter data about the use of the technology; some mechanisms will be inherited by the neighbour group (e.g., open/close mode, define a list of participating users, indicator definition, etc…) with some specific information:
  - technology_type: the type of technology (e.g., sensor, a digital service, a Decision Support Systems, etc…).
  - the level of adoption: a comparison will need at least two sub-groups:
    - adopter: data collected in farm using the technology.
    - non-adopter: data collected in farm not using the technology.
  - the coordinator can create other groups (e.g., partial adopters); it is important to stress that a farm can participate in multiple groups.
- Data entry: a user with valid credentials can push a new set of indicators into the technology space; the indicators need to be inserted in a specific level of adoption of the technology; each user has a separate space and has no access to other users' data. The system has an UPSERT method of data entry.
- Benchmarking: the coordinator and all the users belonging to the group can access the summary of the results; the individual data is not shown, the users access only the averages related to each adoption level.

3 Conclusions

The Benchmarking and Performance Indicator Monitoring Tools provide a flexible way for farms to evaluate their productivity and the sustainability of the practices they adopted, as well as the efficacy of the developed digital solutions.

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