Integrated framework for NBS assessment

Integrated framework development to support Theme 3 benefitting particularly Themes 1.1 and 1.2 (led by OsloMet; supported by all partners, except WUR). This WP will focus on the development of the integrated framework for NBS assessment. The framework will contain a toolbox type repository of tools, methods, technologies and standards/guidelines developed in WP2-5.

1. Introduction

The aim of this report is to customize and support urban planners, consultants and other stakeholders/end-users in making decisions concerning the planning and design of NBS at various scales. The central part of the framework (open access) will be a decision support type tool that will enable selection of optional intervention strategies by using multiple criteria based on wide-ranging benefits and costs identified in WP2-5.

2. RainSolutions - the concept of decision support tool for Nature Based Solutions projects

Nature Based Solutions (NBS) is a promising trend in the area of urban planning. As the NBS term suggests, its main focus is to bring feasible solutions inspired by nature [8]. Main goals of the NBS are to support sustainable urbanization, restoration of degraded ecosystems, climate change mitigation and improvement of risk management and resilience. Nature Based Solutions are strictly relevant to at least 8 of 17 Sustainable Development Goals. In a past years numerous research projects, publications, reports, case studies, guidebooks and frameworks were developed. In the rapidly changing environment, the massive amount of data makes it hard to follow new text guidebooks, which also become quickly outdated. The following report presents a new data-driven approach for NBS framework building and management. The role of RainSolutions tool is to provide interface between user and deliverables of institutions involved in NBS research area. Machine learning algorithms are used for classification and matching the best fitted cases study for user needs. The software will provide the best matching content based on users preferences. Partial automation will benefit the user through time optimization of easier NBS project design and management.

Climate change is a phenomenon of climate variations over longer period of time – e.g. decades, centuries or even longer. With climate change formerly desolated areas can become green and full of life. On the other hand, green lands over time can turn into deserts, where life is reduced to minimum. Those are perfectly natural events occurring over the geological history of Earth – possibly resulting from Earth's self-regulatory mechanisms [1].

With civilization development, man began to grow more independent of nature. Expanding civilization brought upon new inventions and possibilities. Strong buildings, fossil fuels, energy from atom, artificial fertilizers allowing the production of previously unattainable amounts of food. All this caused the incredible growth of humanity, which in recent decades have begun to take astronomical proportions.

Currently, over 54% of citizens in the world live in urban areas While in Europe alone this number grows to 73% [2]. It is a natural environment for a man, whom mostly discarded nomadic lifestyle. For thousands of years urbanization has provided shelter, security, development opportunities and was concurrently growing with civilization development. It is estimated that even in the lowest-income countries, population in cities will reach 50% in 2050year [3]

However, we are approaching the moment, when the nature has begun to claim its own. The effects of climate change, caused inter alia by human activities, have taken a new, so far unknown form. In most urbanized areas, natural ecosystems have been completely destroyed [4]. In others, they have been reduced and changed to such an extent that they are no longer able to fulfill their original functions [5-7].

One of the natural environments' basic functions is water resources management. The water cycle is stabilized through various complementary environmental elements. The obvious environmental function is continuous fresh water supply. This supply is realized with a network of rivers, streams and ground water. The quality and water purity is ensured by wetlands, peatlands or underground filtration layers. The water surplus from sudden heavy rain or seasonally melting snow is adopted not only by water containers, but also flora and well fertilized soil. This way, even heavy downpours do not cause great damage in the natural ecosystem.

Unfortunately following the escalating urbanization, the environment is degrading to the level, where big cities cannot be protected by nature any longer. In the countryside, the same rainfall or elevated water level has far less negative repercussions, than in highly urbanized city. The civilization progress came with many tools keeping human life safety. Deaths caused by flooding are no longer a big concern. However, the issue now shifted towards finances. Local floods in the area of high density of buildings can result in huge financial losses over short period of time. In more developed and richer cities those losses can be quite severe.

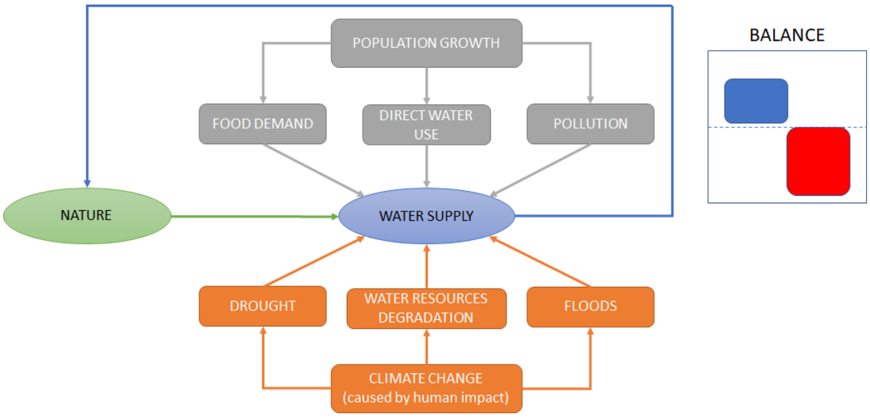

Fig 1. Water supplies and quality provided by the nature are affected by multiple factors introduced by population growth. Balance for more and more places on the earth becomes negative.

Cities growth came naturally with development of rainwater collecting, storage and transportation. Most of the developed cities use flood embankments, retention tanks and/or storm canals. However with dynamic city development comes increasing maintenance and production cost. Therefore, it is crucial to implement new resilient and sustainable water management solutions.

Nature Based Solutions

Nature Based Solutions (NBS) is a promising trend in the area of urban planning. As the NBS term suggests, its main focus is to bring feasible solutions inspired by nature [8]. Main goals of the NBS are to support sustainable urbanization, restoration of degraded ecosystems, climate change mitigation and improvement of risk management and resilience. The principle of NBS is to follow and support the Sustainable Development Goals (SDG) [9]. NBS are strictly relevant to nine from seventeen goals: 3-Good health and well-being, 6-clean water and sanitation, 9-Industry, innovation and infrastructure, 10-Reduced inequalities, 11-sustainable cities and communicates, 13-Climate action, 14-Life below water, 15-Life on land and 17-Partnership for the goals.

Fig 2. Nature Based Solutions are strictly relevant to at least 8 of 17 Sustainable Development Goals

NBS brings together climate protection, improvement of inhabitants living conditions, social equality and social health. NBS water management techniques can be applied to highly urbanized and agricultural areas [10]. Great examples of such management are: green roofs [11-12], permeable layers [13], constructed wetlands [14-15], rainwater harvesting [16-17], swales [18-20], filter strips [21-23], rain gardens [24-26], accidental wetlands [27], biofilters [28-30], bioretention [31-34], detention ponds or sedimentation ponds [35-38]. These solutions not only play a part in water infrastructure betterment, but also can bring new previously unattainable services to grey infrastructure. NBS main advantage is their multi-dimensionality. Looking at an example: on one side e.g. green roofs are a great retention container reducing flooding danger, while on the other side the vaporization of accumulated moisture in biomass reduces ambient temperature and the risk of heat island creation. Listing further, green roofs are a perfect place for relaxation, positively affecting the inhabitants' mood and mental and physical health. It is proven that, the overall aesthetic values of the surroundings increase the inhabitants sense of belonging in the community, their proclivity to care for the communal areas. Moreover it has a positive impact on the criminality decrease. The big advantage of NBS is their durability. In contrast to the grey infrastructure, green infrastructure has natural regenerative properties, which in longer run have massive impact on financial aspects.

Problem definition

NBS is a fairly new, but promising field of study. Thanks to its multi-dimensional reach NBS's can serve many purposes and have a huge advantage over grey infrastructure. Unfortunately these solutions are often complex in design and maintenance. NBS are dynamic systems, opposite to grey infrastructure. NBS's proper functionality is the resultant of many variables, starting from the development, construction, localization, management history, local climate and finishing on its behavior and changes in time [39]. There are many well-made physics-based models for various NBS types, however, in practice each application should be approached individually from the very beginning. Grey infrastructure usually has well defined functionality, while NBS cannot always be easily judged. Single NBS can serve many purposes depending on classification, and those purposes may be hard to evaluate in terms of economy.

This is a blocker to broader utilization of NBS in urban planning. Therefore it is crucial to implement new, easy to use tools allowing simple NBS implementation and maintenance.

In recent years, many actions were performed to develop consistent guidelines for the planning, design and implementation of NBS projects. Those actions results in development and dissemination of frameworks available through specially created platforms (knowledge base). Over the last few years, a number of great projects have been carried out which resulting in countless valuable materials. Projects such as EKLIPSE [40], ThinkNature [8], Naturvation [41], Natural Hazards – Nature-based Solutions [42], and many others deliver high quality framework for NBS planning and maintenance.

Figure 3 shows the simplified flowchart of NBS project design and operation [8]. In general NBS diversity brings along complexity in planning and design. Nevertheless there are some basic steps that can be derived as common for most of the applications. An NBS project itself can be directed in multiple ways. Therefore it is good practice to use one of the available frameworks. Otherwise many mistakes can be made, usually by not advanced NBS planners.

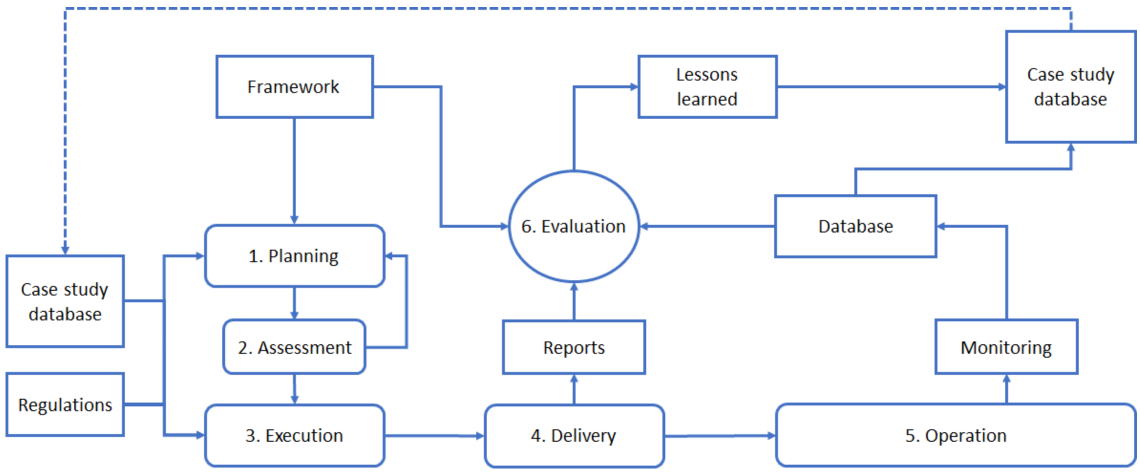

Fig 3. Simplified NBS project flowchart. Concept based on ThinkNature handbook [43]

The project operation is started with planning, where the problem is defined. Problem definition is created based on project requirements and capabilities, at the same time an appropriate stakeholder should be picked. During the project lifetime, the types and numbers of stakeholders can vary, so it is crucial to give maximum effort for engaging them into the project. When stakeholders are gathered and problem definition is initially defined, the scoping analysis should be performed. The analysis encompasses literature, regulations and case study database review to check if the initially defined problem is not ill-conditioned (if some expectations cannot be met). At this stage it is very important to have experienced NBS advisory board. Otherwise this task could become very time consuming, especially when the team runs an NBS project for the first time. The good practice is to define alternative scenarios and designs. The project goals, along with scenarios and design are confronted and matched with NBS outcomes in an assessment phase. The assessment and planning should be performed in a cycle to ensure that all of the requirements and expectations are reasonable, and catch early on the ones that cannot be met. There can be some unexpected reasons for unfulfilled requirements of the project, so the assessment is imperative to at least predict some of the risks with implementing the particular NBS solution. When the assessment is finished, the project can go to execution phase. The execution covers preparation of detailed design documentation, assessment reports and reports on business case and project funding. In order to meet all of the criteria, a lot of specialists from various fields need to be engaged. At the end of this process all of the documentation flows to Delivery phase. When the NBS infrastructure is successfully delivered, the actual NBS operation can begin. Most of the NBS can operate without extended maintenance, however it is good practice to introduce some monitoring system. NBS can be then evaluated based on the collected data. The evaluation can provide some lessons learned, but also extend the knowledge on the particular case study. The collected information and lessons learned could be useful in the future NBS projects.

The collected knowledge from previous NBS projects is usually presented in a form of a framework. Frameworks bring tremendous amount of high quality content. As NBS gains more recognition the volume of published materials is rapidly growing. At this rate the amount of accessible data and information can quickly become problematic to people not strictly involved with NBS. Moreover it is human nature to apply straightforward solutions, and officials or policymakers usually want to use easy approach rather than go deep into technical details. From this conclusions it seems that a good way to proceed is to develop simple, clear and usable NBS planning and maintenance tool. A tool that will have a user-friendly interface, where the user does not need to go into much detail and can use it with only the basic knowledge.

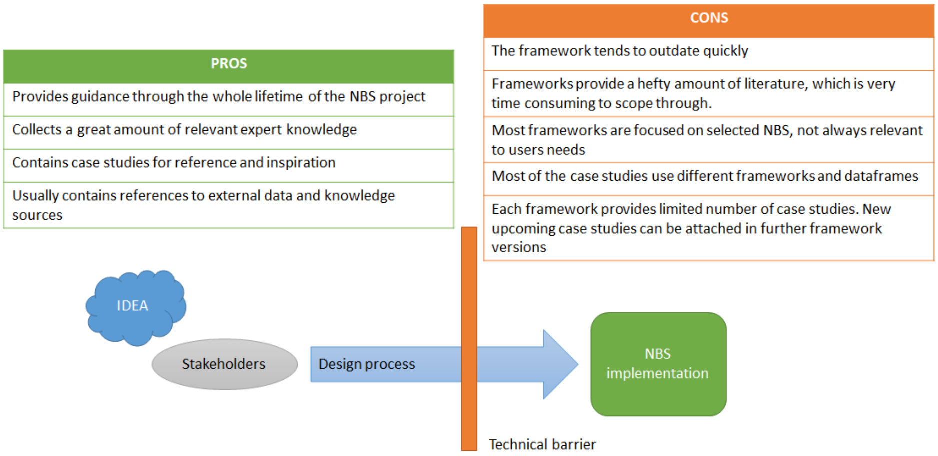

Fig 4. Standard NBS framework – pros and cons

Fig. 5 presents some of the requirements from perspective of the end user and the tool owners/admins. The end user can have different level of expertise and experience. The interface should be open access with no forced need to log onto the system. It should be intuitive enough to not require tutorials. The information visible to the user should be updated frequently and up-to-date. From the tool owner side the code base needs to be easily scalable, designed in a way to easily allow for extension with new features. A good architecture at the beginning allows for time savings in the long run. It will also be a responsibility of the tool owner to maintain the design and good code practices. Another point is low budget. Public institutions usually have a limited budget tied to some project financing. With the commencement of said project funding can become scarce. Furthermore public institutions can have a hard time financing proficient expert programmers, thus the more reason for the tool to be cheap in maintenance.

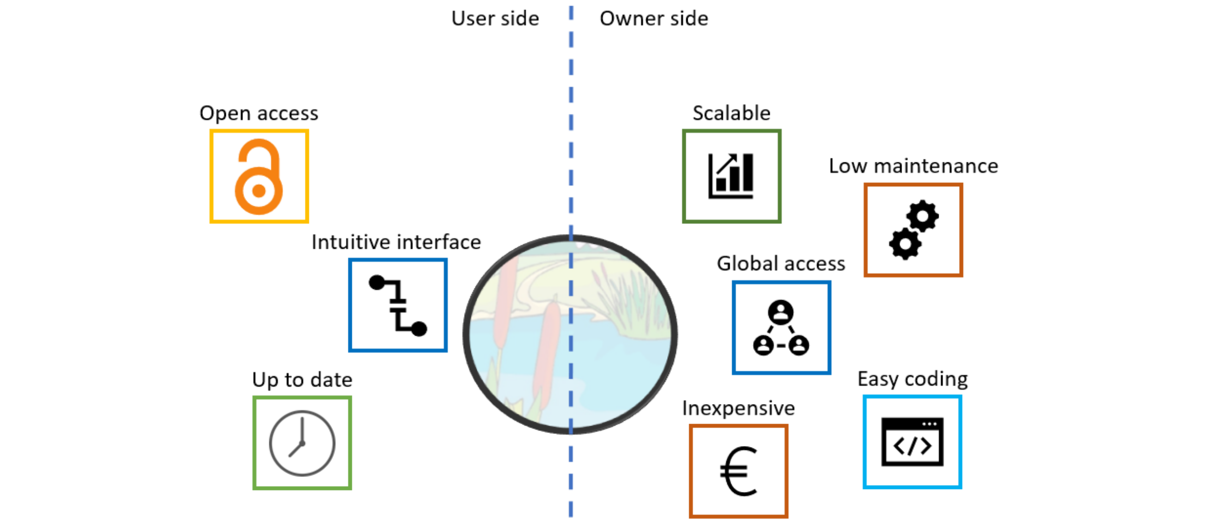

Fig 5. Requirements for interactive platform

The concept or RainSolutions decision support tool

The goal of the RainSolution project is to develop an interactive support tool to overcome the technical barriers in NBS projects. Figure below shows NBS project development framework combined with RainSolutions support tool. The circle with graphics represents the backend of the application. The cloud, according to the name represents the components of the tool operating in a cloud (computing/storage) manner.

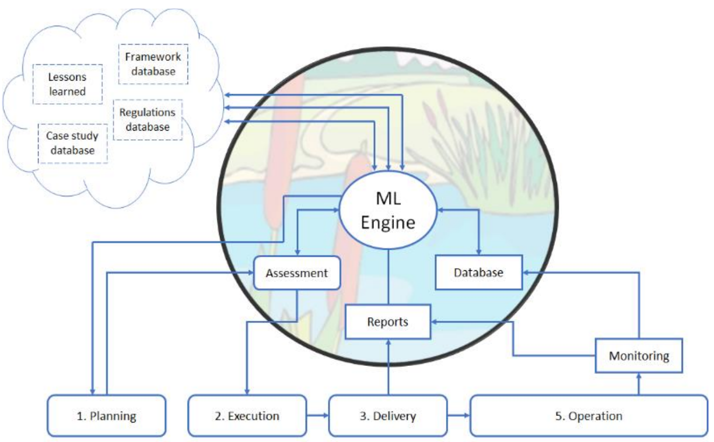

Fig 6. Concept of NBS decision support tool - RainSolutions

As previously stated the NBS project starts with planning (1). At this point, the RainSolutions tool collects the user information: project name, coordinator, starting date, duration, budget (if possible), funding unit, location (country, city, coordinates) etc. The project goals are initially defined by the user. It is important that at this stage the data, which will be further processed on the decision side of the RainSolutions tool, are explicit and follow strict rules.

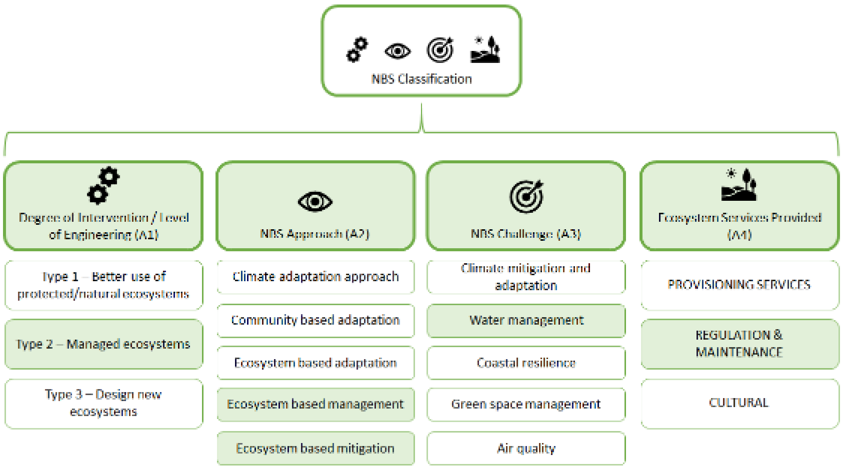

Fig 7. Project questionnaire (exemplary page)

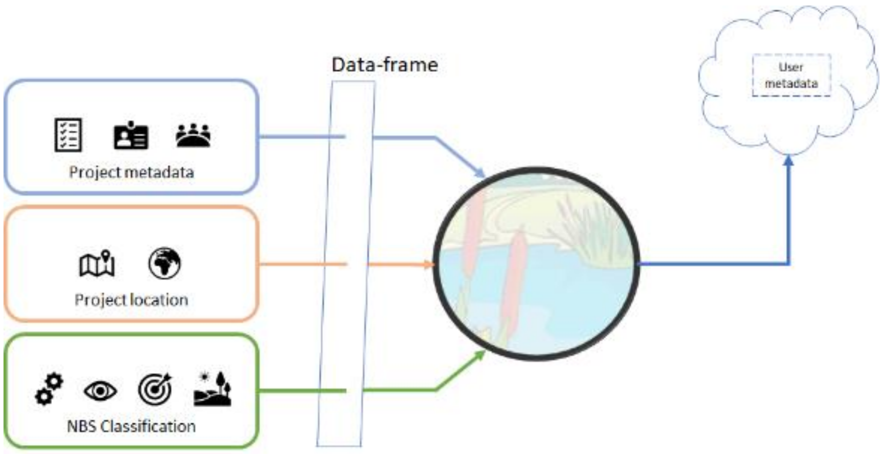

Fig 8. Collecting project metadata

Based on the provided information, RainSolutions software will use ML Engine and its own database classifiers to match project to one of the implemented categories. Then from the classification results, user is supplied with all relevant frameworks, guidelines, case studies and lessons learned. This way user is provided with all the knowledge base useful for NBS implementation.

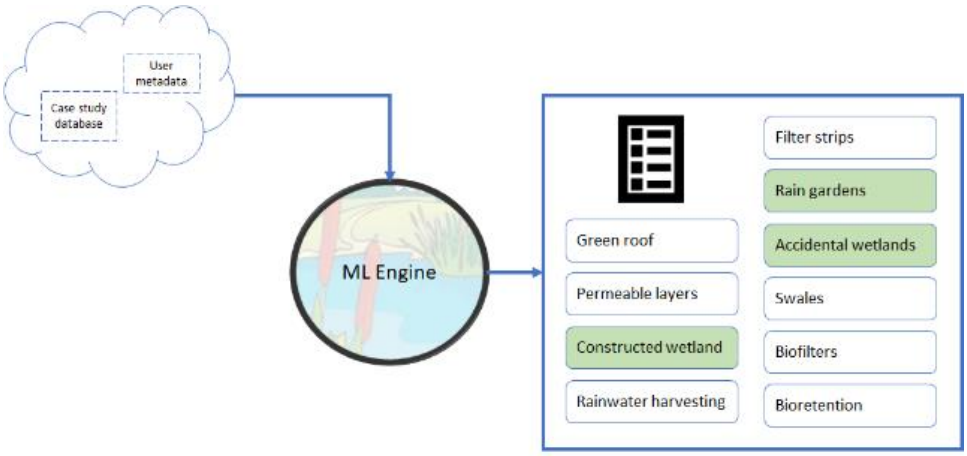

Fig 9. Case study classification

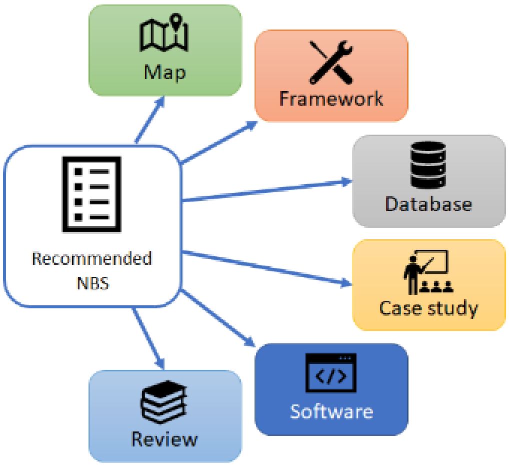

Fig 10. NBS recommendation

The second part of the RainSolutions tool is connected with more advanced calculations. As the data supplied at the beginning is fed to the database, in the second part the tool requires collected measurement data. At this stage it is also very important that the provided data are complete. In the previous stage the project was generally classified, so in this stage the tool can select appropriate DataFrame (i.e. data package) for the selected NBS class. Depending on the NBS class the DataFrame requirements may vary. Data in the DataFrame may include climatic data, available infrastructure, geology, landform etc. After DataFrame collection, it is passed to the database and the RainSolutions tool fits the best performing model for a given task. The model is selected from available implemented set of models. The models should be treated as a standalone packages, which could and should be expanded and updated by RainSolutions contributors.

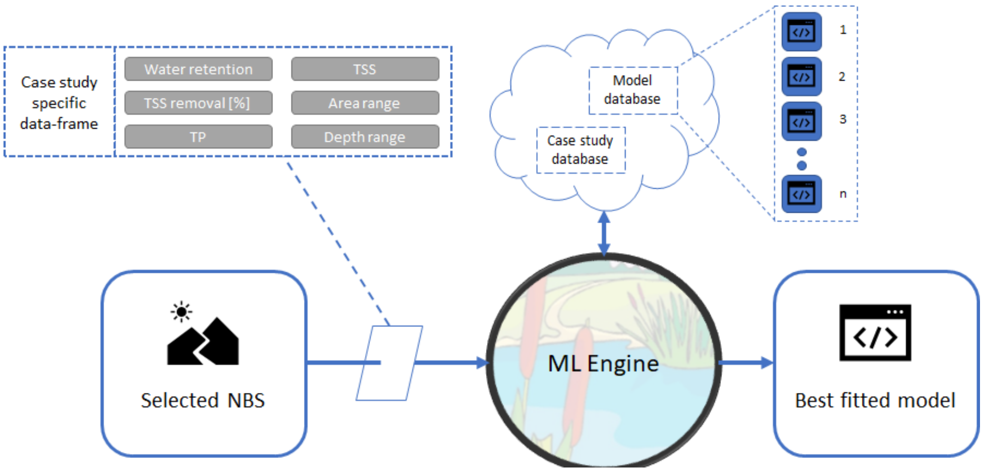

Fig 11. NBS software classification

Execution (2) is the next step of RainSolution framework. At this point user develops detailed design of the project. The RainSolution software provides the best fitted framework along with a set of case studies as inspiration and reference for the project in question. The user can also use proposed RainSolutions model to predict the best configuration of the designed/selected NBS. For some cases, RainSolution may not propose any model and only the frameworks/case studies. However as the model pool and the collected DataFrame database expands, the possibilities for fitting project model to success increases. Delivery(3) and operation (5) are final steps of each successful NBS project. Detailed and standardized reporting is a good practice of every engineering project. Already developed NBS frameworks usually offer guidelines for reporting. The RainSolution software will offer electronic version of the reports. To summarize, the RainSolution tool make NBS planning process more user friendly. It will gather user input and measurement data to expand RainSolutions database and propose the best NBS selection at the time of usage. It is recommended that the user will monitor the NBS operation and update the RainSolutions database. New data will be helpful in building new ML models, updating them and in the end providing more accurate NBS selection. The planning and design cycle is supplied within RainSolutions reporting capabilities of the tool. The created reports could be used for project evaluation, and internally they will be used for creating case studies stored in the tool database. Comparison to other case studies can be helpful but not mandatory. Unified report system and objective evaluation will be helpful to verify the project successfulness and can be useful for reporting to funding institutions.

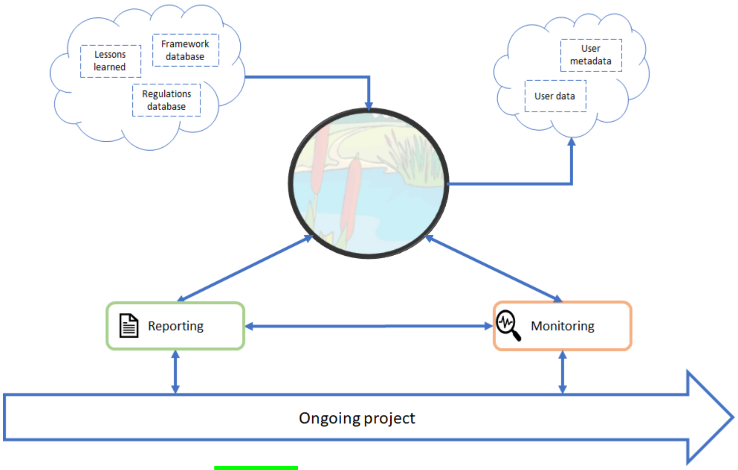

Fig 12. Operation phase

Summary

Nature-Based Solutions become a competitive alternative for gray infrastructure in a context of sustainable and resilient cities. In the past years numerous research projects, publications, reports, case studies, guidebooks and frameworks were developed. The amount of data makes standard approach based on text guidebooks outdated in a rapidly changing environment. The following report presents a new data-driven approach for NBS framework building and management – a RainSolutions tool. The tool shall provide interface between user and deliverables of institutions involved in NBS research area. The software will provide the best matching content based on users preferences. The core of the tool is user preferences classification via machine learning algorithms to match the best fitted case study. It will simplify the desired NBS search and research process, ultimately leading to less time consuming NBS project design and management.

3. RainSolutions - the concept of framework for Nature Based Solutions knowledge sharing

The previous chapter focused on the concept side of the NBS planning and management support toolbox. Integration of AI systems in the toolbox would allow for the user to easily pick and get accustomed with the best planning strategies and implementation of the NBS to match the particular scenario. The usage of ML on the toolbox's backend, however, requires a lot of data to build, train and test the model. The following chapter showcases the toolbox concept as a share platform, built to share NBS framework and therefore being a global framework for NBS.

State of the art

The current times are filled with data, shared on multiple platforms and in different forms. The data is produced by various people with different technical background. In order to understand that data, it needs to be consumed, translated to a format understood by a model or a tool, and then finally it can be used to provide some conclusions. The input data can be presented in any form, i.e scientific research publications, raw measurement data, books, websites, graphs, conference video recordings, maps, software, reports, presentations. If the user is not proficient in the topic or has some good understanding of the fundamentals, it could be hard to find, and critically process the data. Access to the data can be simple, but categorization and filtration of it to match particular use case can and should be automated for time saving and sustainability.

Fig 13. Data producing

The tech market provides many advanced publication websites. Each of them having million users around the world. The search engines are designed specifically to easily find materials based on tags, keywords and filters. Those same filters can be used then to setup a notification subscription, to be in touch with the most recent papers. Some of the biggest players as of 2022 are presented in figure below. On an example well known Google Cloud it is worth noting that ML modelling is very common for extracting data from various types of materials. Google

Cloud offers great AI and ML packages, which can be easily combined with each other. The ones that are clearly visible in all Google tools are speech-to-text transcription, text detection on image or pdf file, categorization of objects on a photo, and many others. All of that is connected to could hosted databases. Similar cloud solutions can be found on Azure or AWS. Usually in order to perform computations with the designed ML model, the cloud services offer the developer to pay only for the used resources minimizing the overall cost of the product.

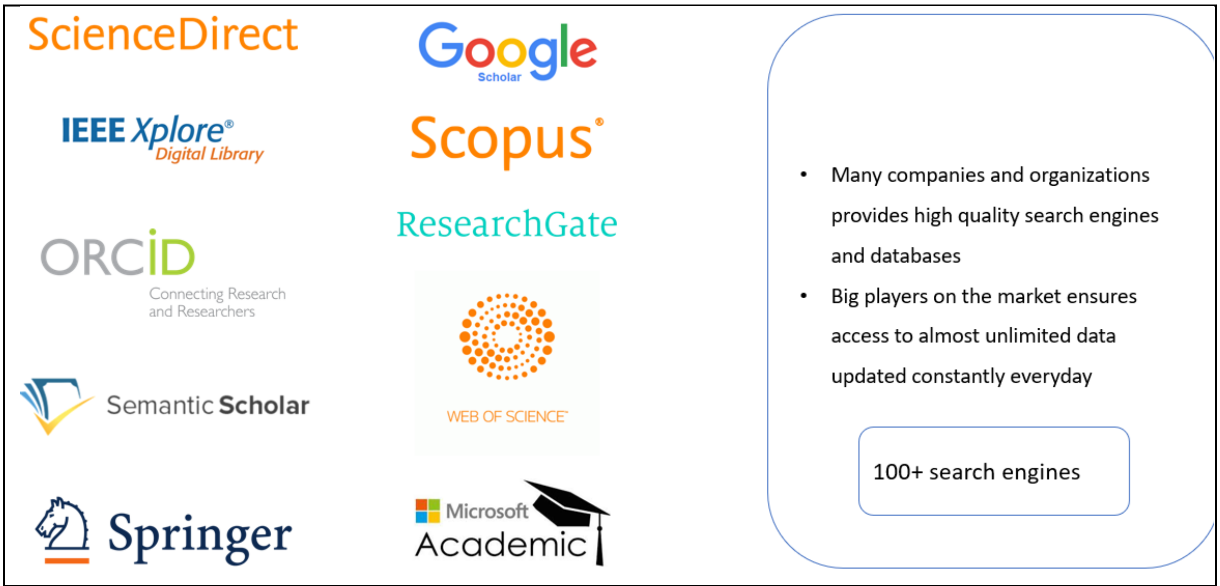

Fig 14. Search engines – big players

The ever growing amount of publications and data itself, created a need to develop such solutions. There is a lot of information easily attainable online, the only problem is a proper extraction and preparation, so the models can be correctly trained. With well-defined models and combination of the tools, the data of different type (visual, document, audio) can be bundled together by categories and presented to the user quickly in one package. The search engines for scientific papers are focused just on the scientific papers. They use AI, but their reach is only academic. This way the platform ensures the presented knowledge is properly vetted and peer revied by other professionals. There is nothing wrong with this approach, but it can be oftentimes limiting. These same professionals also present their findings on conferences, or there are facilities producing relevant data for NBS, but they are not properly published and could be useful upon further inspection.

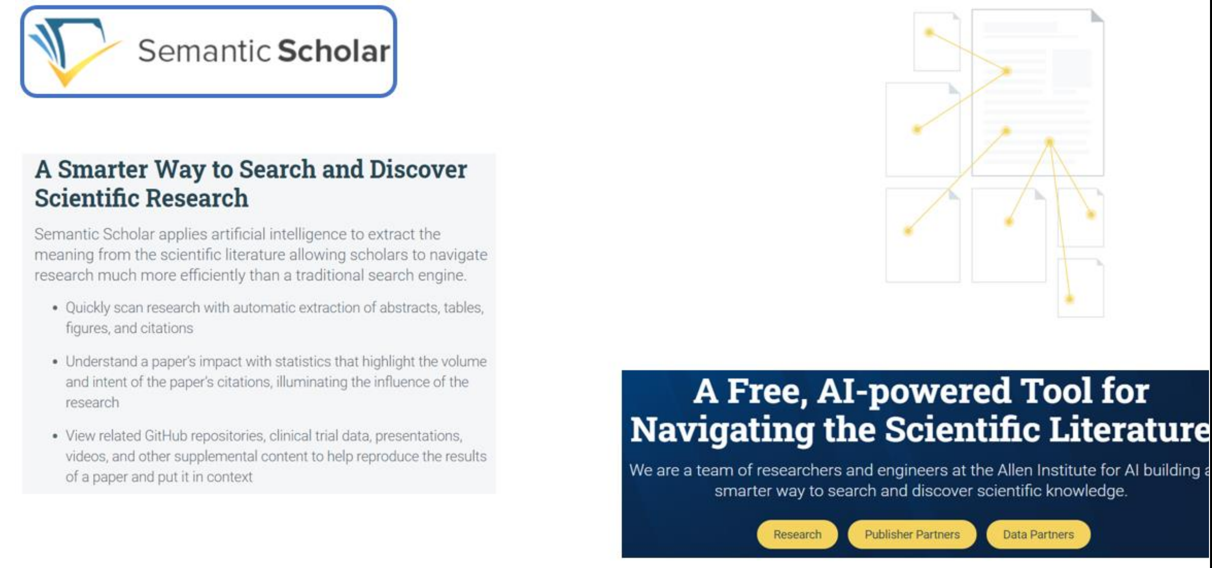

Fig 15. Search engines – AI enhanced

Figure below presents various types of data generated by research units and/or other research producers. The data in such scenarios is not structured the same or having a certain standard in mind. Having no common format makes it harder to collate and collaborate with. In order to achieve simplicity, flexibility, sustainability and reduce time in search efforts, the data needs to be properly extracted, tagged, categorized. In a way it needs to be normalized to be consumed.

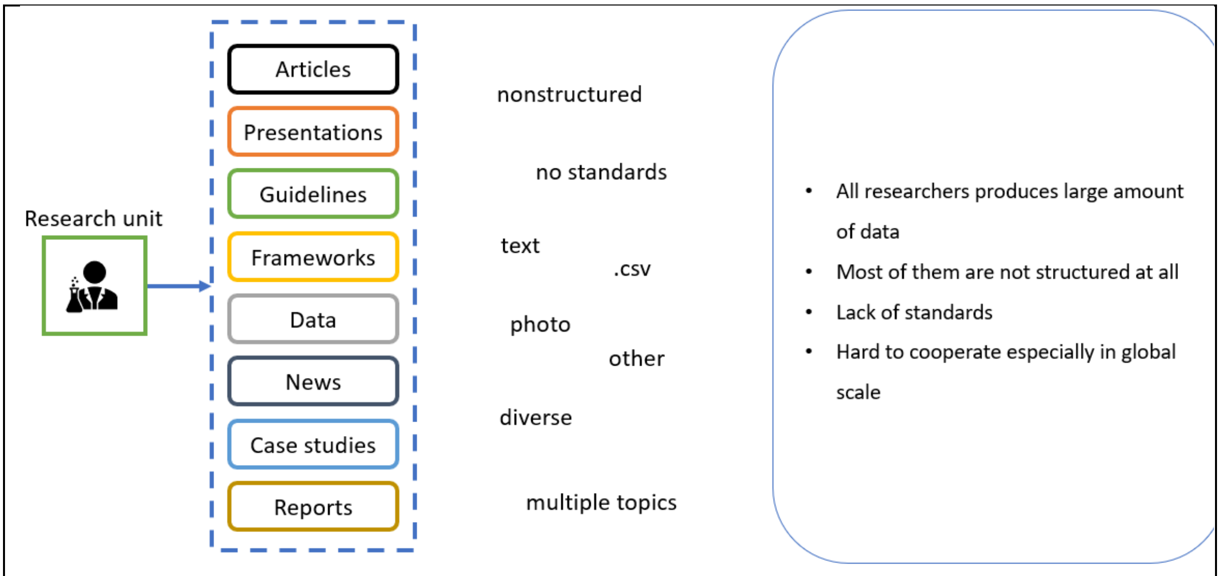

Fig 16. Data types

Inside the bundle of data, there are the search engines of big publishing houses. The publishers are enforcing certain standards on the papers and books they publish. Having set ground rules and boundaries helps in the first stages of data normalization. Therefore publishers have easier task, and do not need very complex solutions over AI based customized text search.

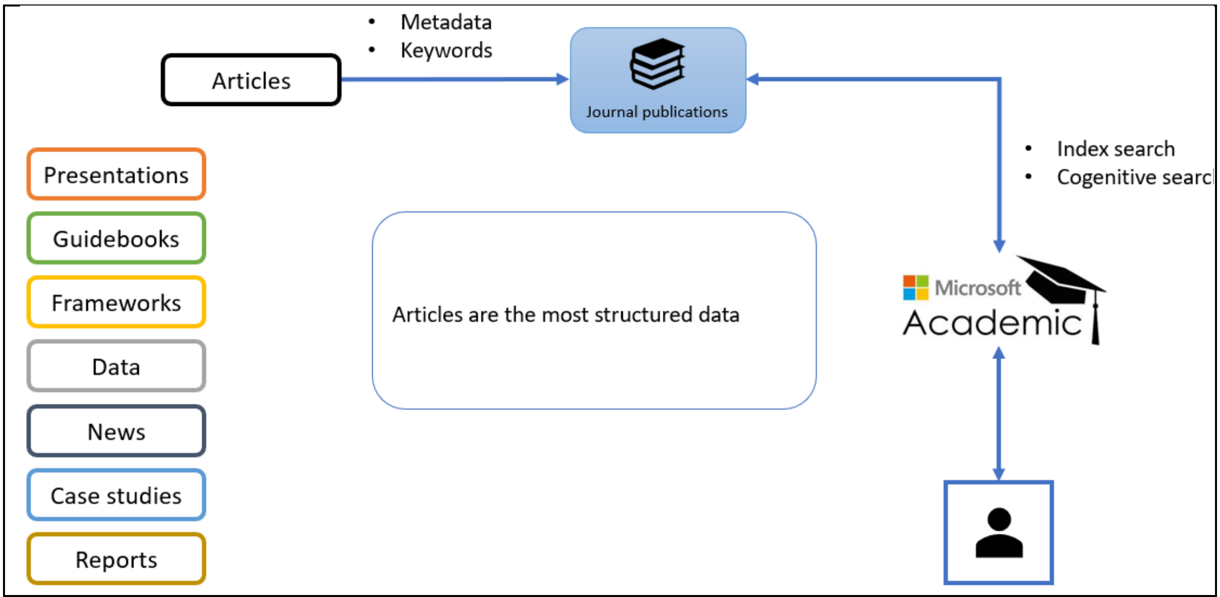

Fig 17. Data types

The data produced during scientific research process not only results in books and articles. This is rather the end result. In the meantime the research team can generate measurement data, reports, presentations and other documents of visual or textual nature. In this sense the publishing houses search engines, and the software collating the published materials (from different publishers) are focusing only on a fraction of available data.

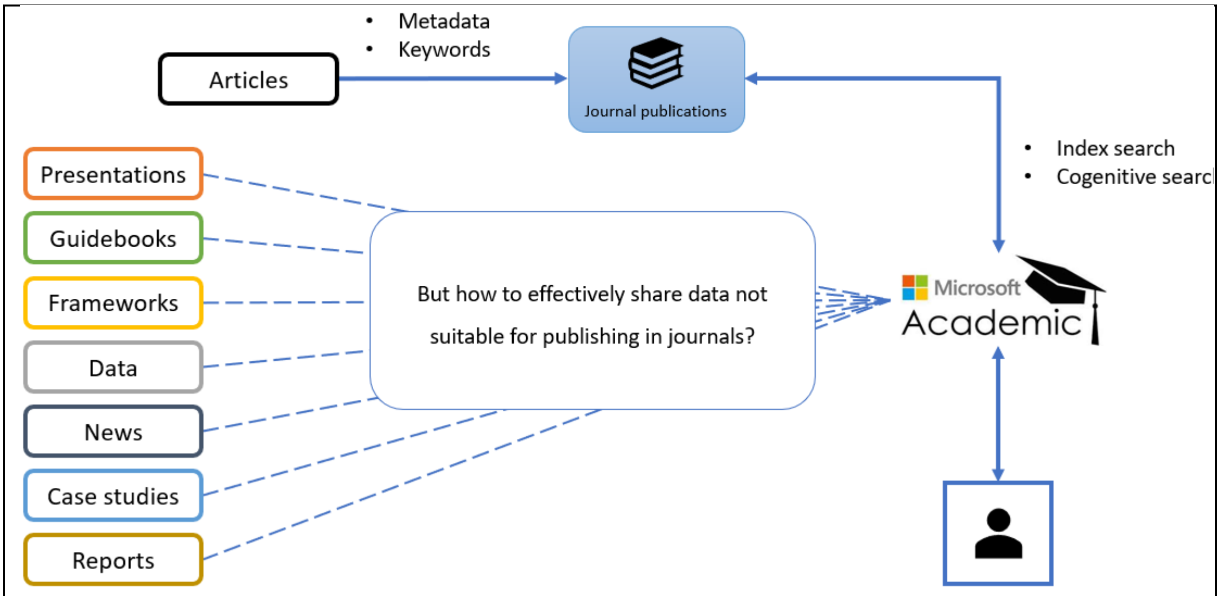

Fig 18. Knowledge exchanges – existing gaps

In the broader spectrum the data becomes non-uniform and requires normalization. The normalization and categorization can be developed implementing ML models. As previously noted on the Google Cloud example there already are tools enabling such normalization. The existing ML models for visual or text data can be mixed together and trained for the specific purpose. This however is only the back-end side of the application. It still needs to be connected to some user friendly interface that is separately implemented.

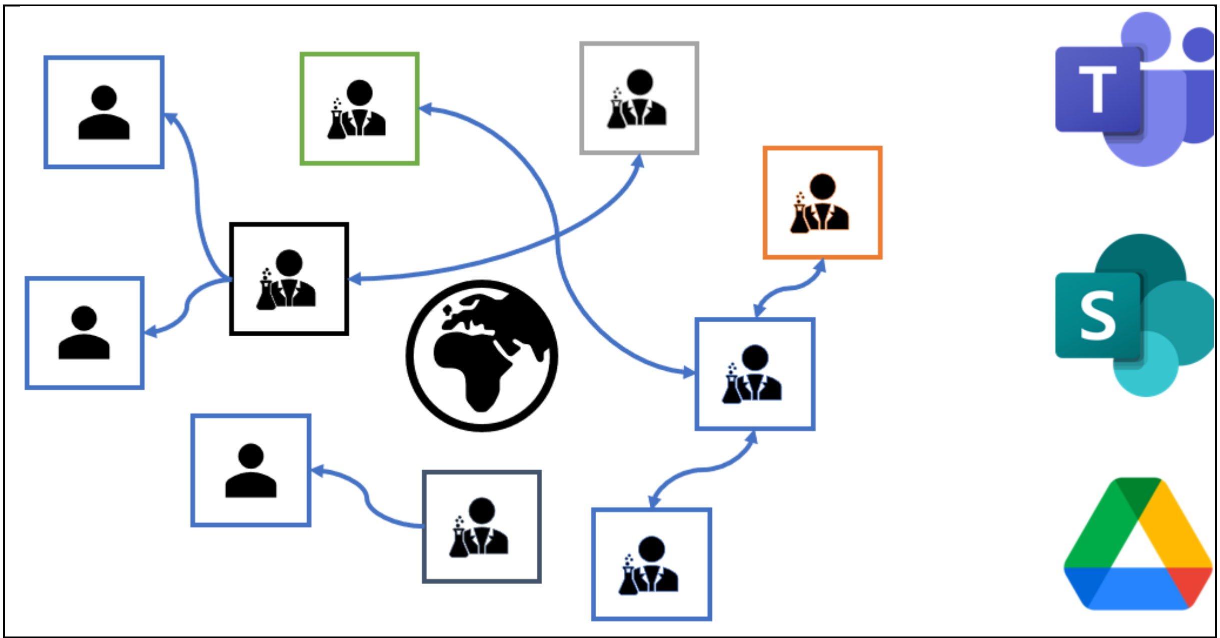

Fig 19. Data users

Most certainly the best knowledge can be found at source, where the user can be sure the source was properly verified. With scientific papers and books, there is this certainty. However at the same time there can be a problem of knowledge expiration. If the original producer of the documents has stopped progressing the topic further, the user needs to search for new viable sources. This issue is very apparent for topics connected with new rapidly improving scientific areas, legislation or development strategies.

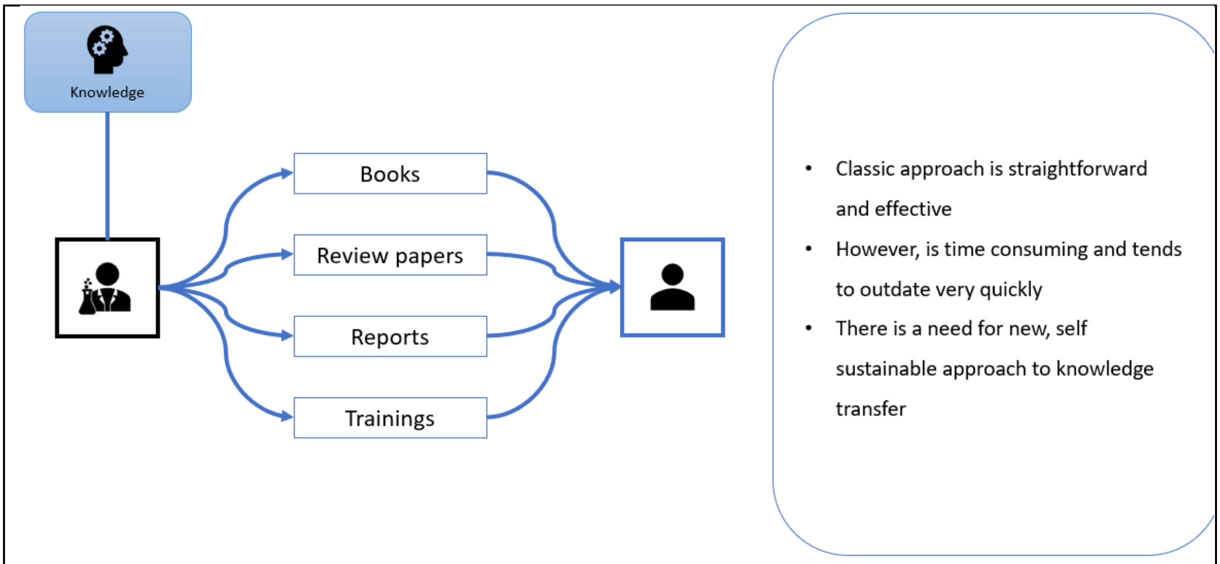

Fig 20. Challenges and opportunities

Requirements

As stated in previous chapter, there are many solutions for effective knowledge publishing. However they have limitations, as usually the publishing platforms focus on one sharing method. There already exist platforms as MS Teams, which integrate many tools in one place under relatively simple interface. The base functionality of MS Teams is chat, video calls and collecting users into groups. It can be extended with apps promoting content sharing of various types and work organization tools. The users are responsible for customization of the tool for their needs. At the same time the whole burden of categorizing the data lies on the users themselves. The group of users can collect the data under local wiki pages (similarly to Wikipedia it is just a big library usually with restricted access) and share the knowledge within their internal group or organization. The drawback of tools like MS Teams is that the sharing is limited to the organization, which most likely creates a hermetic environment of experts. Users external to the organization cannot benefit from the expert materials. MS Teams allows collaboration, but the results of that collaboration usually have no global reach.

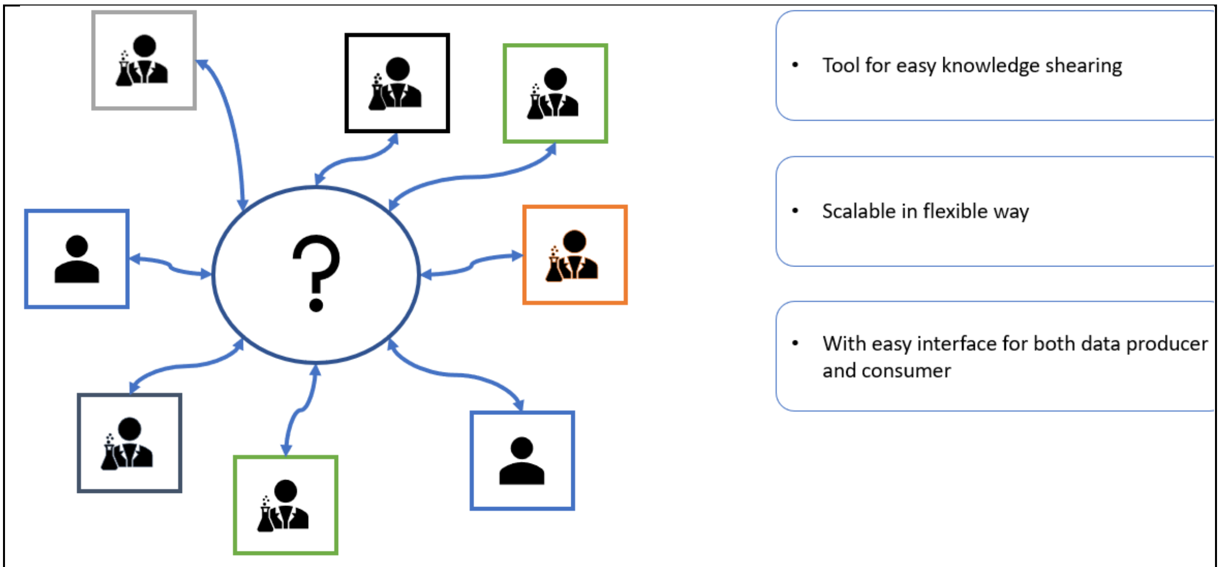

Fig 21. Requirements

Framework for NBS knowledge sharing with RainSolutions platform

The following chapter presents concept of RainSolutions platform, as a framework for NBS knowleadge sharing. The Fig.22 presents fundamental parts of the platform:

- Knowledge producer – scientists, engineers and industry employees publishing vetted materials i.e. articles, books, presentations, databases. The materials under one producer form a Story in RainSolutions platform. The Story is created inside the platform and its main responsibility is to store and collate NBS project development tutorials. The Stories are created based on the materials provided by the producers and stored in RainSolutions database. The producer has a responsibility to pick most relevant parts of the materials they want to share, collate them and mark with appropriate keywords.

- Knowldege consumer – the end user of RainSolutions platform. Main user of the front-end interface. The person that customizes the search process and searches NBS via RainSolutions platform.
- Database – storage of knowledge producers' Stories. It is a basis of initial ML models training. The database should be expanded with new Stories, so the ML models become more accurate with time.
- ML Engine – backbone of the framework. Combination of machine learning models used for data classification, which can simplify the search.

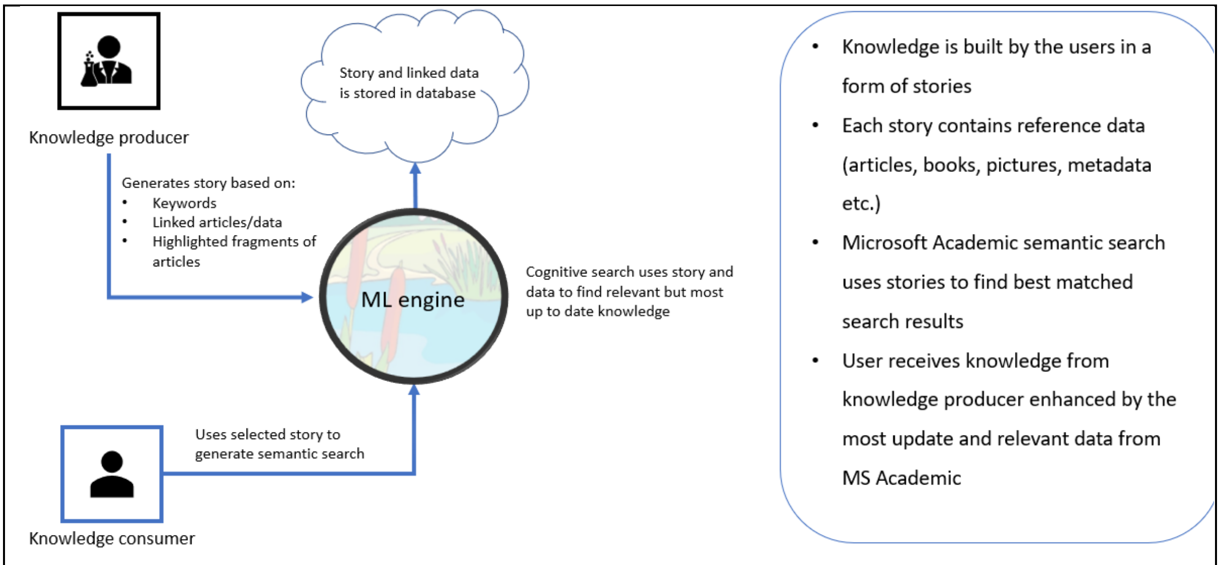

Fig 22. RainSolutions framework – main stakeholders

The RainSolutions framework has 3 layers of execution. The core without, which the framework cannot exists are the knowledge producers' Stories. The Stories are a collection of data produced during lifetime of an NBS project. The producer is responsible for adding the data in a Story and marking parts of it with keywords. The Stories are generated from data categorized (chronologically, thematically, logically) including metadata (keywords). An example of the Story would be a tutorial on green roofs implementation in urban areas. The tutorial could consist of case studies, trainings, useful pointers, lessons learned, links to existing norms and legislations.

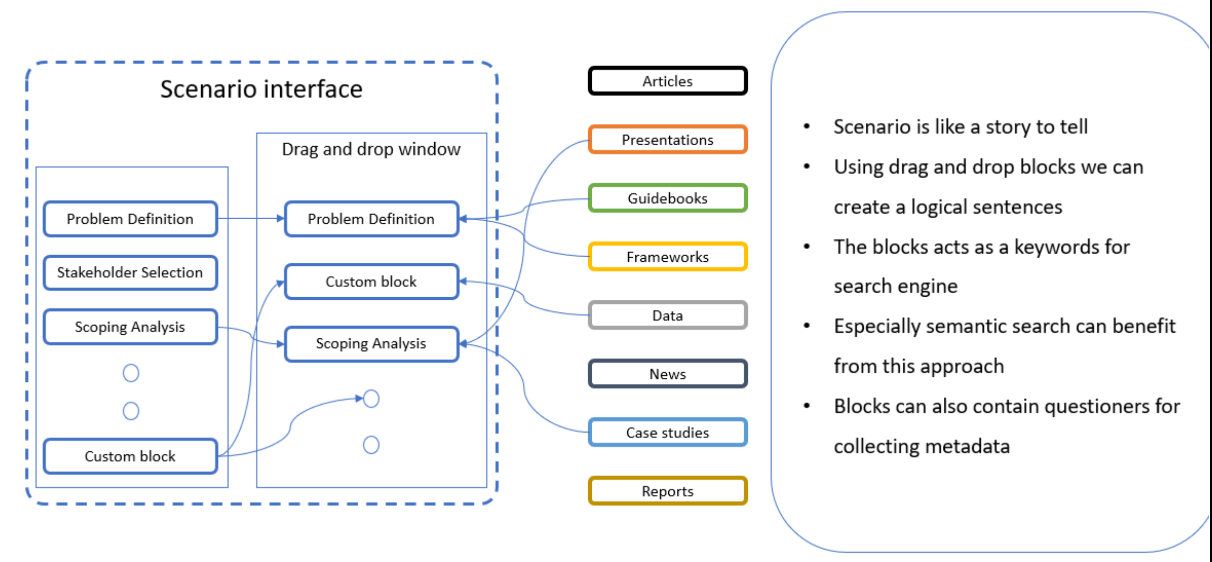

Fig 23. RainSolutions framework – creating scenario

The categorized data provided by the knowledge producer is fed to the fundamental layer – ML engine. The data is used to continuously train and verify the model. Depending on the data provided, the ML engine could recognize parts of the images and extracting documents excerpts. In the first layer, the knowledge consumer could view the images and documents relevant to the NBS they want to apply. From the consumer perspective the RainSolutions framework should be a searchable encyclopedia, connecting relevant information into bundles.

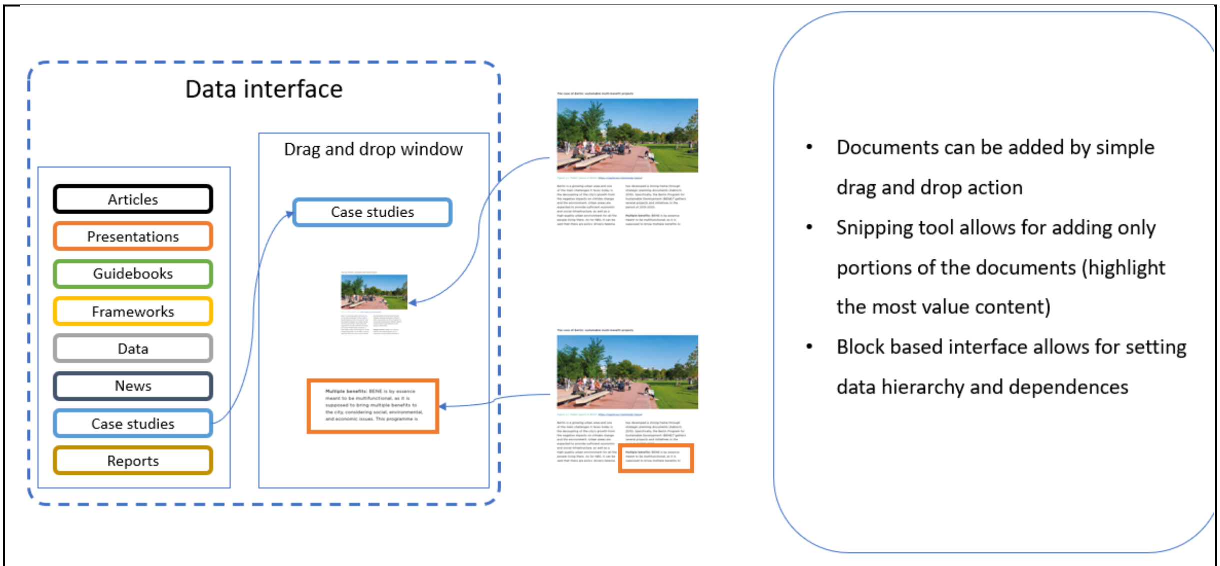

Fig 24. RainSolutions framework – interface tools

The knowledge consumer and producer layers are in fact front-end interfaces to the framework. From these layers the users have access to visual tools aiding the process of uploading data and searching through it. The data supplied can scope many NBS categories – most likely it will be use cases and databases. The computation (ML engine layer) can be offloaded to cloud computing solutions. Ready-made customizable machine learning models can be combined to offer more flexibility in supplied NBS data.

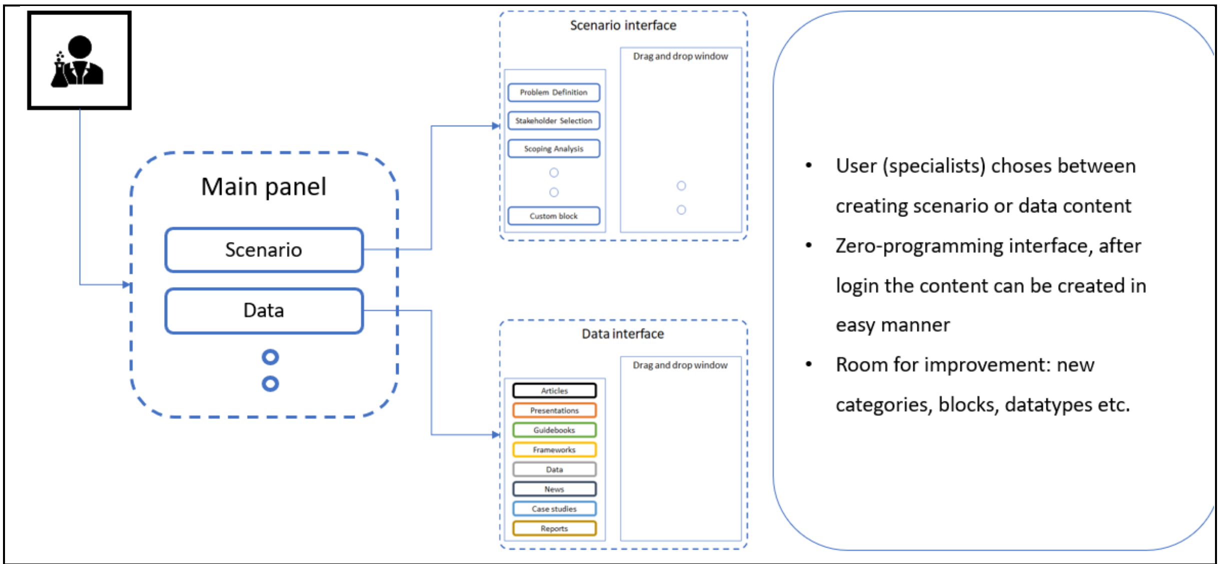

Fig 25. RainSolutions framework – knowledge types

The ML engine layer, as well as the whole software architecture is managed by system admins. Initially the role of system admin is assigned to OsloMet – Oslo Metropolitan University. With the development of RainSolutions framework, the system admin role could be extended to other research units. Apart from the access to code base, system admins can assign producer and consumer roles to the framework users. The producers' voluntary contribution ensures the up-to-date data feed to the framework. The admin role is to select and accept producers into the framework. From the side of the consumer, it should be a default role of a person accessing the framework. The consumer can be anyone from the public or private sector, NGO or just any person interested in NBS. The framework should have open-access, so the default consumer layer is available to anyone from the internet. This way it will be easier to propagate the framework to the interested parties.

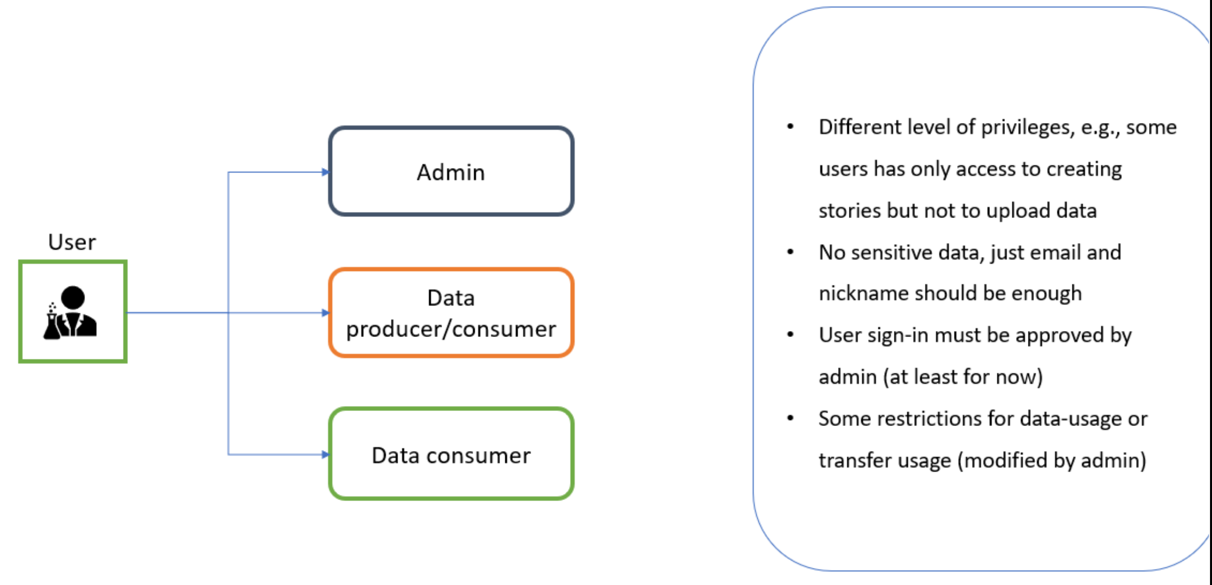

Fig 26. RainSolutions framework – stakeholders categories

RainSolutions framework does not categorize the knowledge producers depending on their competencies or activity. It is the producer free will to put any form of data into the system. There is no mandatory data format – the producer can choose to supply only use cases or databases, or he can provide both at the same time. At the same time the consumers are not categorized either. The personalization of the search depends strictly on them.

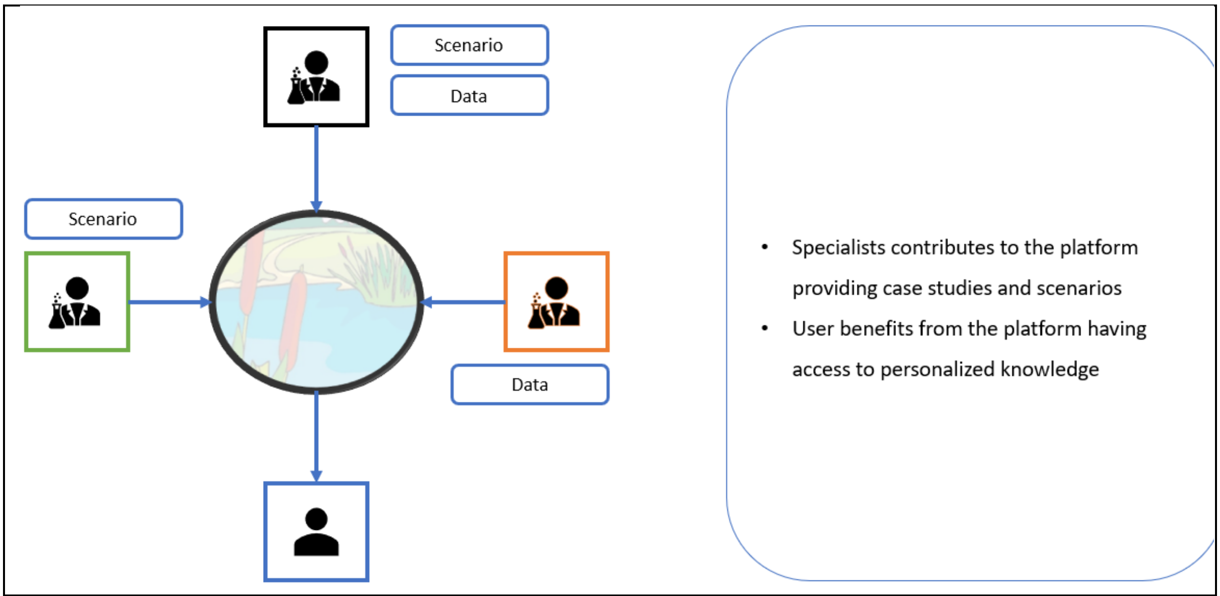

Fig 27. RainSolutions framework – data producer types

For the consumer the introduction to the search starts with base scenarios to get accustomed with NBS. Upon further inspection of the scenarios, if the consumer is interested in particular NBS area, the RainSolutions should help him with future read suggestions. This way the user can build upon his own knowledge and understand the topic better.

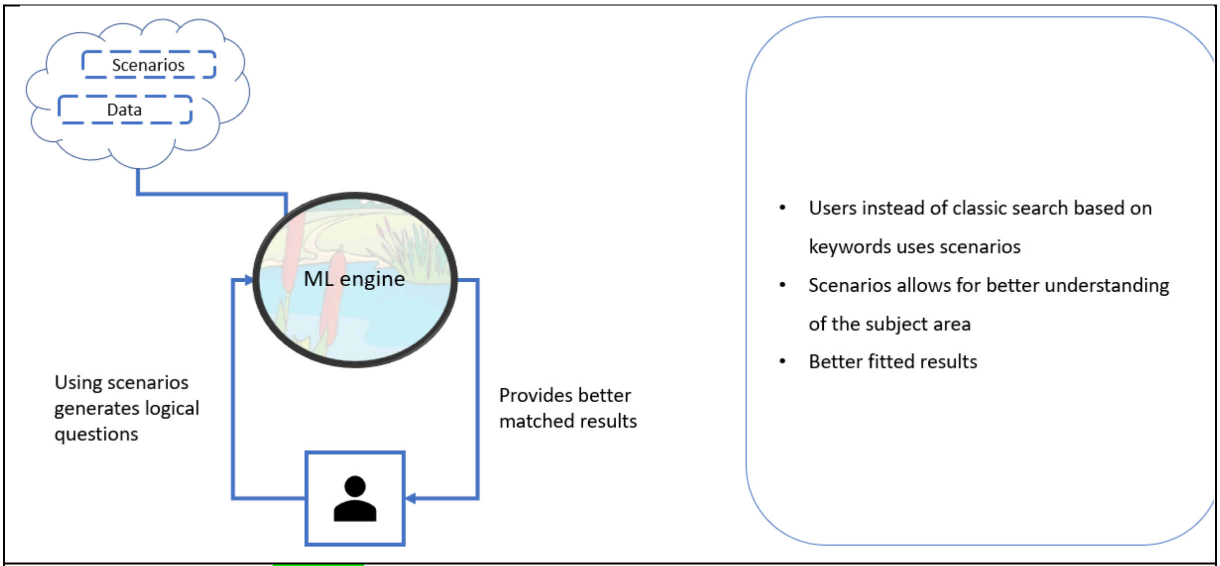

Fig 28. RainSolutions framework – user perspective

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