Article

A Novel Crop Shortlisting Method for Sustainable Agricultural Diversification across Italy

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Abstract: Whilst current policies recognize the impacts that changes in climates and markets have imposed on the Italian food system, less attention is given to the development of systematic approaches to identify alternative cropping systems across Italy and the European continent. In this article, a novel evidence-based crop shortlisting method was developed to address crop diversification needs for Italy as an example for the whole of Europe. In order to shortlist possible options from a pool of 2700 crops, a crop–climate–soil matching exercise was performed across Italian territory, and crops with more than 70% suitability were chosen for further analysis. In the second phase, a multi-criteria ranking index was employed to assign ranks to chosen crops of four main types: (i) cereals and pseudocereals, (ii) legumes, (iii) starchy roots/tubers, and (iv) vegetables. To provide a comprehensive analysis, all of the abovementioned criteria were compared for both major crops that are grown in the region and potential underutilised crops (UCs). The results of evaluation of four major criteria (namely (a) calorie and nutrition demand, (b) functions and uses, (c) availability and accessibility to their genomic material, (d) possession of adaptive traits, and (e) physiological traits) revealed the potential for teff, faba bean, cowpea, green arrow arum, Jerusalem artichoke, Fig-leaved Gourd, and Watercress. We discuss the implication of utilising such systematic approaches to crop selection and developing transformative solutions for food security with the aim of providing a primer for mainstreaming UCs in policy and investment plans.

Keywords: crop diversification; Italy; neglected and underutilized crops; rank summation index; RSI

1. Introduction

Whilst eradication of hunger and malnutrition is one of the major targets (Goal 02) of the United Nation’s Sustainable Development Goals [1], it is now highly likely that many of the goals and targets related to food and nutrition security will not be reached by 2030. Unsustainable practices, broken land systems, loss of biodiversity and monocultures, are among the major points of vulnerability in the global food system that is currently relying only on 30 crops to fulfil 90% of the calorie needs [2–4]. However, only three crops (wheat, maize, and rice) provide over 75% of the calorie requirements. At the global level, out of 300,000–500,000 higher plant species, about 30,000 are edible and approximately 7000 have been either cultivated or collected for human consumption [4,5]. Out of the 17 SDGs which focus on several critical global issues, the underutilised crops (UC) show the potential to contribute to SDG 1 (no poverty), 2 (zero hunger), 12 (responsible consumption and production), and 13 (climate action).

Apart from cases that can be made for a wider adoption of underutilised crops for land restoration, dietary, and economic diversification, many of these crops remain unknown to
the public and wider agricultural stakeholders, and for this reason are not included in the local, regional, and global agricultural development programmes [6,7]. One of the major barriers to the inclusion of minor crops in the developmental programmes worldwide is dispersity and lack of knowledge about their suitability at different geographic scales and in relation to local needs [8]. Despite the existence of global knowledge base for underutilised crops [5], more effort is needed to evaluate and shortlist possible cropping options at national and regional scales based on specific needs and priorities.

Italy’s agriculture is affected by the impacts of climate change [9,10] such as loss of agrobiodiversity [11], land degradation, and economic marginalization [12]. One of the important implications of climate change for agriculture is the change in growing seasons and cropping systems. For example, the sowing date for annual crops might be affected as the result of changes in temperature regimes. Another implication of climate change is the change in the cropping system, particularly for rainfed agriculture, which has a direct impact on the productivity of such systems. In fact, declines are expected due to climate change for the yield of key crops such as wheat [9], olive [10], and grapevine [13]. Changes in precipitation patterns are strongly linked to the loss of biodiversity and land degradation due to increases in extreme events (droughts and floods) [14], which will in turn impact traditional high-input agriculture [15–17]. As a result, land cover under agriculture in Italy has been reduced drastically over the last few decades. This poses a severe threat to the sustainability of the agricultural systems and food security [9,10].

Farm net revenues have been found to be sensitive to seasonal changes in temperature and precipitation, with strong consequences from severe changes in climate [18]. This will lead to increases in economic inequality for vulnerable groups (women and other marginalised groups). Global warming will also unevenly affect Italian regions, particularly for regions that are less developed and more dependent on agricultural production [19,20]. This will in turn lead to more economic disparity in Italy, which will trigger a wider challenge to the environmental systems.

As a result of climate change, heat stress, pest and disease activity, higher evaporative demand (which reduces water availability), and higher variability of rainfall will negatively affect future agriculture across Europe [21]. Globally, existing food systems are unsustainable due to a few major issues, e.g., environmental impacts; risk to human health; intensive resource use; and the use of depleting non-renewable resources such as mineral fertilizer, pesticides, ground water, and certain energy sources [22–25]. Italy’s rich agrobiodiversity, particularly its herbaceous landraces, have been threatened due to a number of reasons [11]. In this regard, innovative and regenerative approaches to agricultural development that take advantage of locally neglected and globally underutilised species can play a major role [3]. Different underutilised species which are available in Italy are either cultivated, semi-domesticated, or in the wild [26]. In such a context, agrobiodiversity can provide a solution to enhance the adaptation of the cropping systems to the future climate and, in turn, increase food production [20].

Species that are resilient to agro-climatic changes; can withstand temperature extremes, drought, and flooding; can tolerate marginal soil conditions; are pest and disease tolerant compared to the current major crops; and are rich in nutrition content exist today and can be adopted for Italian agriculture. Collating knowledge about UCs is the first step towards addressing the gap in mainstreaming these crops. However, a major challenge remains: identification and shortlisting of crops using a multitude of criteria that are relevant to local adaptability of these crops. The traditional approaches to crop selection, however, are less evidence-based and more ad hoc. That is, crops are chosen based only on a few criteria, such as economic potential and general environmental conditions. This may restrict the adoption process for new crops by an industry that is risk averse [3], warranting the need for development of comprehensive evidence bases that can reduce the initial implementation risks. Evaluating the suitability should start with climate and soil matching to understand the degree of adaptability of certain crops, followed by evaluation
of (a) calorie and nutrition demand, (b) functions and uses, (c) availability and accessibility to their genomic material, (d) possession of adaptive traits, and (e) physiological traits.

In this paper, a multidisciplinary approach for developing an evidence base for crop shortlisting for Italy is discussed. This approach utilises a combination of crop–climate matching and a novel evidence base for shortlisting crops based on the rank summation index methodology. The output of this process is a list of high-potential crops that can be adopted for development across Italian territory. The article presents the results and outlines further actions to mainstream shortlisted crops.

2. Materials and Methods

A literature search was conducted to help to establish the status quo on the availability of the published information on neglected and underutilised crops (Section 2.1). This provides a preamble for further development of the methodology. UCs for Italy were then selected in two phases based on two different but complementary approaches: (i) selection based on the pedoclimatic suitability (Section 2.2) and (ii) ranking and shortlisting using a multi-criteria index based on a wider range of crop and nutritional properties (Section 2.3). Figure 1 shows the methodological processes that were used in this article.

Figure 1. Flowchart of methods used in this analysis.

2.1. Current Literature on UCs in Italy

A preliminary literature search was conducted in Scopus [www.scopus.com] using queries to answer the following main questions:
What are the current views on UC across Italy
What crops are considered underutilised and are the focus of research in Italy
What portion of current research is allocated to UC in Italy

The search was limited to title, abstract, and keywords; articles between the years 2001 and 2019 were considered.

Query: TITLE-ABS-KEY ((underutilised OR neglected) AND (crop OR fruit OR vegetable OR plant) AND (Italy)) AND PUBYEAR >2000 AND PUBYEAR <2020.

The availability of literature for a few major crops such as wheat, maize, grapevine, and potato were also evaluated as follows (only crop name was replaced in each literature search:

Query for wheat: TITLE-ABS-KEY ((wheat) AND (Italy)) AND PUBYEAR >2000 AND PUBYEAR <2020.

2.2. Suitability Assessment

The objective of the suitability assessment was to select the crops that achieve pedoclimatic suitability more than 70% within 1 km map resolution. The suitability assessment was performed using the method developed by Jahanshiri et al. [8]. The suitability of the 2492 UCs that are currently available in the Global Knowledge Base (GKB) for the underutilised crops database [5, 27] was tested. Detailed data on species’ niche requirements were obtained from the database. These variables include optimal and marginal temperature range and total rainfall requirement (assuming a rainfed system). Other variables include optimal soil requirements in terms of acidity (pH in water), texture, and depth. This information was then used to determine separate suitability for each variable for each season. The total suitability was determined on a scale of 0 to 100, based on the average of all suitability indices. A threshold of 70% was used to select crops that can survive within all pedoclimatic conditions of Italy.

A regular grid of 1 km interval was first developed across Italy, leading to about 1 million locations. The crop selection algorithm was run for each location. As a result, at each location, an array of crops and their suitability for 12 possible seasons per year was developed. Table 1 shows a portion of the database that resulted from running the crop-climate matching algorithm for all locations on Google Cloud Engine facilities (https://cloud.google.com, accessed on 9 March 2020). CropID refers to the ID of the crop in the Global Knowledge Base for underutilised crop [5]. Data under each month refer to the estimated suitability for the crop-season starting that month. All data are available at https://zenodo.org/record/4563293#.YqqgycZR2is, accessed on 9 March 2020.

Table 1. An excerpt from the crop suitability database for Italy [28].

| Longitude  | Latitude  | CROP_ID | Climate Suitability | Soil Suitability |
|------------|-----------|---------|---------------------|-----------------|
| 12.1791667 | 47.0875   | 10001000011 | Jan 0 0 0 0 0 0 0 0 0 0 0 | 67 |
| 12.1791667 | 47.0875   | 10001000096 | Feb 0 0 0 0 0 0 0 0 0 0 0 0 | 67 |
| 12.1791667 | 47.0875   | 10001000123 | Mar 0 0 0 0 0 0 0 0 0 0 0 0 | 82 |
| 12.1791667 | 47.0875   | 10001000143 | Apr 0 0 0 0 0 0 0 0 0 0 0 0 | 82 |
| 12.1791667 | 47.0875   | 10001000144 | May 0 0 0 0 0 0 0 0 0 0 0 0 | 82 |
| 12.1791667 | 47.0875   | 10001000124 | Jun 0 0 0 0 0 0 0 0 0 0 0 0 | 82 |
| 12.1791667 | 47.0875   | 10001000034 | Jul 0 0 0 0 0 0 0 0 0 0 0 0 | 100 |
| 12.1791667 | 47.0875   | 10001000116 | Aug 0 0 0 0 0 0 0 0 0 0 0 0 | 55.6 |
| 12.1791667 | 47.0875   | 10001000065 | Sep 0 0 0 0 0 7.5 38 41 7.5 0 0 0 65.8 |
| 12.1791667 | 47.0875   | 10001000083 | Oct 0 0 0 0 0 0 0 0 0 0 0 0 | 82 |
| 12.1791667 | 47.0875   | 10001000109 | Nov 0 0 0 0 0 0 0 0 0 0 0 0 | 82 |
| 12.1791667 | 47.0875   | 10001000041 | Dec 0 0 0 0 0 0 0 0 0 0 0 0 | 82 |
2.3. Multi-Criteria Index to Rank and Select UCs

As the second stage, the list of selected UCs with an average suitability of more than 70% were shortlisted based on a wider range of crop and nutritional properties. Out of the 18 categories on which the selected crops from the suitability assessment belong (Section 3.2), 4 categories that are important for food and nutritional security were selected. These four categories of crops were (i) cereals and pseudocereals, (ii) legumes, (iii) starchy roots/tubers, and (iv) vegetables.

Out of the crops selected from the climate suitability assessment, a few prominent and potential crops from each category were selected to study the nutritional and crop data (Table 2). Some of the major crops were included into each category to compare with the UCs. Production of the selected crops in Italy was initially evaluated in order to confirm whether the selected crops are underutilised or major.

Table 2. List of selected crops used to study nutritional and agronomic data in Italy.

| Crop                        | Scientific Name | Crop Type       |
|-----------------------------|-----------------|-----------------|
| **Cereals and Pseudocereals** |                 |                 |
| Rice                        | Oryza sativa    | Major           |
| Maize                       | Zea mays        | Major           |
| Wheat                       | Triticum aestivum | Major         |
| Sorghum                     | Sorghum bicolor | Major           |
| Foxtail Millet              | Setaria italica | Underutilised   |
| Canihua                     | Chenopodium pallidicaule | Underutilised |
| Teff                        | Eragrostis tef  | Underutilised   |
| Proso Millet                | Panicum miliaceum | Underutilised |
| **Legumes**                 |                 |                 |
| Soybean                     | Glycine max     | Major           |
| Chickpea                    | Cicer arietinum | Major           |
| Bramble Wattle              | Acacia victoriae | Underutilised  |
| Faba Bean                   | Vicia faba      | Underutilised   |
| Bambara groundnut           | Vigna subterranea | Underutilised  |
| Cowpea                      | Vigna unguiculata | Underutilised  |
| **Starchy Roots/Tubers**    |                 |                 |
| Potato                      | Solanum tuberosum | Major       |
| Sweet Potato                | Ipomoea batatas | Major           |
| Green Arrow Arum            | Peltandra virginica | Underutilised |
| Jerusalem Artichoke         | Helianthus tuberosus | Underutilised |
| Hausa potato                | Solenostemon rotundifolius | Underutilised |
| **Vegetables**              |                 |                 |
| Rhubarb                     | Rheum rhaponticum | Underutilised |
| Fig-leaved Gourd            | Cucurbita ficifolia | Underutilised |
| Watercress                  | Nasturtium officinale | Underutilised |
| Endive                      | Cichorium endivia | Underutilised   |

Selection Criteria

Different crops and crop types have different performances in terms of productivity, uses, and resistivity to adverse biotic and abiotic conditions. The Rank Summation Index (RSI), which is a multi-criteria selection method, was implemented to select crops for detailed climate suitability assessment and yield prediction [29,30]. In RSI, ranks of the individual or subcategories were summed and ranked again based on the sum of ranks. The RSI is an established method that has been used in several food and other agricultural-related rankings and selection of cultivars/genotypes [31–35].

Here, the criteria to select the crops were based on seven major categories: food and nutritional value, adaptive traits, other special uses, germplasm information, physiological properties, production knowledge, and production and economic data. These major categories were further divided into 30 sub-categories. Each category was divided into
subcategories where necessary. The data were collected from trusted sources, including research papers, blogs, and websites. All the references are available here.

3. Results

3.1. Current Literature on UCs in Italy

For our search query, only 85 articles were found in Scopus for UCs. The year with the highest number of articles published was 2018 (12 articles), followed by 2019 (10 articles). One article was published in each of the years 2002, 2006, 2013, and 2014, while no articles were found for 2003. There was a total of 918 articles for wheat, 649 for maize, 649 for grapevine, and 365 for potato during the 2001–2019 period for the above query. There was a clear gap between published articles on major crops and UCs. It should be noted that these results represent the initial search findings only, and articles were not removed after detailed review. Also, there may be other papers for UCs that did not belong to the criteria used above. For example, if the “underutilised” or “neglected” was missed in either title, abstract, or keywords, they would not count as UC. Variation of the available Scopus indexed articles for major crops and UCs is shown in Figure 2.

![Figure 2. Variation of Scopus indexed articles for wheat, maize, grapevine, potato, and UCs in Italy during the 2001–2019 period.](image)

3.2. Climate Suitability Assessment

The distribution of top suitable crops is shown in the Figure 3. The count represents the number of points (longitude and latitude) on which that crop achieved more than 70% suitability. The crop list contained 633 crops from GKB, belonging to 18 broad categories: aromatic crops, beverage crops, cereals, fibre crops, fodder crops, forage crops, fruits, legumes, medicinal crops, nuts, oilseed crops, ornamental/landscape crops, pesticidal crops, spice crops, starchy roots/tubers, sugar crops, vegetables (fruit), and other/unspecified/unknown crops.

3.3. Multi-Criteria Index to Rank and Select UCs

3.3.1. Food and Nutrient Values

Based on the data availability, three sub-categories were considered under food and nutritional value: nutrients and proximate (carbohydrate and protein), vitamins (vitamins A, B1, B2, B3, and C), and minerals (Calcium, Iron, Phosphorus). Tables A1–A3 show the nutrient properties and ranking of major crops and UCs under each macronutrient, vitamin, and mineral, respectively. Then, the ranks of all the nutritional parameters were summed and the final nutritional ranking was calculated (Table 2). Teff (cereals and pseudocereals), faba bean (legumes), green arrow arum (starchy roots/tubers), and watercress (vegetables)
were ranked top in each category under the food and nutrition value (Table 3). When considering all crops (underutilized and major crops) in each category, both teff (cereals and pseudocereals) and green arrow arum (starchy roots/tubers) ranked top, which proves their nutritional potential over major crops.

Figure 3. The distribution of top suitable crops for Italy (from crop–climate matching algorithm).

Table 3. Ranking of major crops and UCs based on nutritional properties.

| Crop                       | Nutrients and Proximate (Rank) | Vitamins (Rank) | Minerals (Rank) | Nutrient All (RS) | Rank All Crops | Rank UC ¹ |
|----------------------------|--------------------------------|-----------------|-----------------|------------------|---------------|-----------|
| **Cereals and Pseudocereals** |                                 |                 |                 |                  |               |           |
| Paddy                      | 5                              | 8               | 7               | 20               | 8             | 8         |
| Maize                      | 6                              | 5               | 7               | 18               | 6             |           |
| Common Wheat               | 1                              | 4               | 3               | 8                | 2             |           |
| Sorghum                    | 2                              | 7               | 4               | 13               | 4             |           |
| Foxtail Millet             | 8                              | 6               | 4               | 18               | 6             | 4         |
| Canihua                    | 4                              | 2               | 2               | 8                | 2             | 2         |
| Teff                       | 2                              | 3               | 1               | 6                | 1             | 1         |
| Proso Millet               | 7                              | 1               | 6               | 14               | 5             | 3         |
| **Legumes**                |                                 |                 |                 |                  |               |           |
| Soybean                    | 1                              | 1               | 3               | 5                | 1             |           |
| Chickpea                   | 5                              | 1               | 3               | 9                | 3             |           |
| Faba Bean                  | 3                              | 1               | 2               | 6                | 2             | 1         |
| Bambara groundnut          | 2                              | 5               | 6               | 13               | 4             | 2         |
| Cowpea                     | 4                              | 4               | 5               | 13               | 4             | 2         |
| **Starchy Roots/Tubers**   |                                 |                 |                 |                  |               |           |
| Potato                     | 1                              | 2               | 3               | 6                | 2             |           |
| Sweet Potato               | 4                              | 3               | 3               | 10               | 5             |           |
| Green Arrow Arum          | 2                              | 1               | 2               | 7                | 3             | 2         |
| Jerusalem Artichoke        | 4                              | 1               | 2               | 7                | 3             | 2         |
| Hausa potato               | 2                              | 4               | 1               | 7                | 3             | 2         |
| **Vegetables**             |                                 |                 |                 |                  |               |           |
| Rhubarb                    | 3                              | 4               | 4               | 11               | 4             | 4         |
| Fig-leaved Gourd           | 2                              | 1               | 2               | 5                | 2             | 2         |
| Watercress                 | 1                              | 2               | 1               | 4                | 1             | 1         |
| Endive                     | 3                              | 3               | 2               | 8                | 3             | 3         |

¹ UC = Underutilised Crop.
3.3.2. Adaptive Traits

The ecological sustainability of the crops was evaluated and ranked based on nine adaptive traits (drought, waterlogging, frost, shade, salinity, acidic/alkaline soil, infertile/poor soil, weed, and pest and disease) (Table 4). However, the availability of comparatively lower records for underutilized crops than the major crops hindered an accurate comparison. Based on the available data, foxtail millet (cereals and pseudocereals), bambara groundnut (legumes), Jerusalem artichoke (starchy roots/tubers), and rhubarb and fig-leaved gourd (vegetables) were ranked top in each category.

Table 4. Ranking of major and underutilised crops (UCs) based on adaptive traits.

| Crop                | Drought | Waterlogging | Frost | Shade | Salinity | Acidic/Alkaline Soil | Infertile/Poor Soil | Weed | Pest and Disease | Score | Rank |
|---------------------|---------|--------------|-------|-------|----------|----------------------|---------------------|------|----------------|-------|------|
| Paddy               |         |              | ✓     |       |          |                      |                     |      |                | 1     | 6    |
| Maize               | ✓       |              |       |       |          |                      |                     |      |                | 6     | 1    |
| Common Wheat        | ✓       |              |       |       |          |                      |                     |      |                | 1     | 6    |
| Sorghum             | ✓       |              | ✓     |       |          |                      |                     |      |                | 2     | 5    |
| Foxtail Millet      | ✓       |              | ✓     |       |          |                      |                     |      |                | 6     | 1    |
| Canihua             | ✓       | ✓            | ✓     |       |          |                      |                     |      |                | 4     | 2    |
| Teff                | ✓       | ✓            | ✓     |       |          |                      |                     |      |                | 4     | 2    |
| Proso Millet        | ✓       | ✓            | ✓     |       |          |                      |                     |      |                | 4     | 2    |
| Soybean             | ✓       | ✓            | ✓     |       |          |                      |                     |      |                | 2     | 4    |
| Chickpea            | ✓       | ✓            | ✓     |       |          |                      |                     |      |                | 2     | 4    |
| Faba Bean           | ✓       | ✓            | ✓     |       |          |                      |                     |      |                | 3     | 2    |
| Bambara groundnut   | ✓       | ✓            | ✓     |       |          |                      |                     |      |                | 4     | 1    |
| Cowpea              | ✓       | ✓            | ✓     |       |          |                      |                     |      |                | 3     | 2    |
| Potato              | ✓       | ✓            | ✓     |       |          |                      |                     |      |                | 2     | 3    |
| Sweet Potato        | ✓       | ✓            | ✓     |       |          |                      |                     |      |                | 1     | 4    |
| Green Arrow Arum    | ✓       | ✓            | ✓     |       |          |                      |                     |      |                | 4     | 2    |
| Jerusalem Artichoke  | ✓       | ✓            | ✓     |       |          |                      |                     |      |                | 9     | 1    |
| Hausa potato        | ✓       | ✓            | ✓     |       |          |                      |                     |      |                | 1     | 4    |
| Rhubarb             | ✓       |              | ✓     |       |          |                      |                     |      |                | 3     | 1    |
| Fig-leaved Gourd    | ✓       |              | ✓     |       |          |                      |                     |      |                | 3     | 1    |
| Watercress          | ✓       |              | ✓     |       |          |                      |                     |      |                | 1     | 4    |
| Endive              | ✓       |              | ✓     |       |          |                      |                     |      |                | 2     | 3    |

¹ UC = Underutilised Crop.

3.3.3. Other Uses

Most of the UCs are multi-purpose crops which are mainly used as a food source. Uses other than as a human food source were considered here. Other uses include animal feed, medicinal purposes, and a range of industrial purposes (Table 5). Food additives, cosmetic/detergent, paper/textile/basketry, construction, and fuel/biofuel were considered under industrial purposes.

According to RSI, both foxtail millet and proso millet ranked top in the cereals and pseudocereals category. Cowpea was selected among legumes, and Jerusalem artichoke was selected from the starchy roots/tubers category. Comparatively lower other uses were reported from the selected underutilised vegetables.

3.3.4. Germplasm

Availability of plant resources is vital for safeguarding the genetic diversity and future expansion of UCs. The magnitude of conservation work was evaluated using the germplasm details (Table 6). The number of territories that have published information on the selected UCs was counted and ranked. Major crops were omitted here due to the availability of a large amount of variety/cultivar information for a wider range of geographic scales. Teff (cereals and pseudocereals), bambara groundnut (legumes), Jerusalem artichoke (starchy roots/tubers), and endive (vegetables) ranked top according to the RSI.
Table 5. Ranking of major and underutilised crops (UCs) based on other uses.

| Animal Feed | Medicinal | Food Additives | Cosmetic/Detergent | Paper/Textile/Basketery | Construction | Fuel/Biofuel | Score | Rank All Crops | Rank UC ¹ |
|-------------|-----------|----------------|---------------------|--------------------------|--------------|--------------|-------|----------------|-----------|
| Paddy       | ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 5     | 1              |           |
| Maize       | ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 4     | 2              |           |
| Common Wheat| ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 3     | 5              | 1         |
| Sorghum     | ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 1     | 7              | 3         |
| Foxtail Millet| ✓     | ✓              | ✓                   | ✓                        | ✓            | ✓            | 1     | 8              | 4         |
| Canihua     | ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 3     | 5              | 1         |
| Teff        | ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 4     | 1              |           |
| Proso Millet| ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 3     | 2              |           |
| Chickpea    | ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 3     | 2              |           |
| Faba Bean   | ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 3     | 2              |           |
| Bambara groundnut| ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 4 | 1 | |
| Potato      | ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 2     | 5              | 3         |
| Sweet Potato| ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 3     | 2              | 1         |
| Green Arrow Arum| ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 1 | 4 | 2 |
| Jerusalem Artichoke | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 4 | 1 | 1 |
| Hausa potato| ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 1     | 4              | 2         |
| Rhubarb     | ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 1     | 1              | 1         |
| Fig-leaved Gourd| ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 1 | 1 | 1 |
| Watercress  | ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 1     | 1              | 1         |
| Endive      | ✓         | ✓              | ✓                   | ✓                        | ✓            | ✓            | 1     | 1              | 1         |

¹ UC = Underutilised Crop.
Table 6. Ranking of underutilised crops (UCs) based on conservation work (germplasm).

| Underutilised Crop | Number of Active Nations | Rank |
|--------------------|--------------------------|------|
| **Cereals and Pseudocereals** | | |
| Foxtail Millet | 10 | 2 |
| Canihua | 1 | 4 |
| Teff | 11 | 1 |
| Proso Millet | 8 | 3 |
| **Legumes** | | |
| Faba Bean | 3 | 3 |
| Bambara groundnut | 7 | 1 |
| Cowpea | 4 | 2 |
| **Starchy roots/tubers** | | |
| Green Arrow Arum | 1 | 2 |
| Jerusalem Artichoke | 5 | 1 |
| Hausa potato | 1 | 2 |
| **Vegetables** | | |
| Rhubarb | 0 | 4 |
| Fig-leaved Gourd | 2 | 2 |
| Watercress | 2 | 2 |
| Endive | 3 | 1 |

3.3.5. Crop Physiological Information

Different physiological parameters such as water use efficiency, radiation use efficiency, harvest index, and potential yield were evaluated for the selected crops (Table 7). Crop physiological information for some of the UCs was scarce. Therefore, the information of one of the genetically closest relatives was used for such crops. For example, information for quinoa (*Chenopodium quinoa*) was used instead of canihua (*Chenopodium pallidicaule*). Similarly, the values of fig-leaved gourd (*Cucurbita ficifolia*) were filled with those of *Cucurbita pepo*, while *Cichorium intybus* was used for endive (*Cichorium endivia*). Canihua and faba bean ranked top among cereals and pseudocereals and legume categories, while watercress ranked top among vegetables. Both green arrow arum and hausa potato ranked top in starchy roots/tubers.

Table 7. Ranking of major and underutilised crops (UCs) based on physiological traits.

| Crop | Water Use Efficiency | Radiation Use Efficiency | Harvest Index | Potential Yield | Rank Sum | Rank All Crops | Rank UC 1 |
|------|----------------------|--------------------------|---------------|-----------------|---------|----------------|---------|
|      | Value (kg/ha/mm)     | Rank                     | Value (g/MJ)  | Rank            | Value (kg/ha) | Rank        |         |
| Paddy | 2.0–10.2            | 7                        | 1.4           | 6               | 0.17–0.56   | 2           | 10,500   | 3       | 18 5    |
| Maize | 10.6–20.3           | 3                        | 0.35          | 7               | 0.25–0.58   | 4           | 10,550   | 2       | 16 4    |
| Common Wheat | 10.1–10.8  | 4                        | 2.16          | 3               | 0.45–0.55   | 1           | 500–9000 | 4       | 12 2    |
| Sorghum | 30.2                 | 1                        | 2.08–3.83     | 1               | 0.3–0.4     | 5           | 12,000   | 1       | 8 1     |
| Foxtail Millet | 25.5                | 2                        | 1.74          | 4               | 0.47–0.98   | 8           | 850      | 8       | 22 7 3  |
| Canihua | 10–15.7             | 6                        | 2.30–2.33     | 2               | 0.3–0.5     | 2           | 4000     | 5       | 15 3 1  |
| Teff | 2                    | 8                        | -             | 5               | 0.3–0.35    | 7           | 3800     | 7       | 22 3    |
| Proso Millet | 17.63               | 5                        | 1.43          | 5               | 0.3–0.35    | 7           | 4000     | 5       | 22 7 3  |
| Soybean | 6.95                 | 4                        | 1.46          | 3               | 0.42        | 4           | 7000–11,000 | 1   | 12 3    |
| Chickpea | 1.1–15.7            | 1                        | 1.56          | 2               | 0.25–0.51   | 2           | 4000     | 2       | 7 1     |
| Faba Bean | 14                   | 2                        | 1.85          | 1               | 0.42–0.77   | 1           | 2000     | 5       | 9 2 1   |
| Bambara groundnut | 0.9–10              | 3                        | 0.24–1.31     | 4               | 0.30–0.45   | 3           | 3000–3000 | 3   | 13 4 2  |
| Cowpea | 3.72                 | 5                        | 1.05          | 5               | 0.28–0.34   | 5           | 2390–3130 | 4   | 19 5 3  |
| Potato | 59.56                | 2                        | 2.41          | 3               | 0.6         | 3           | 100,000  | 1       | 9 3     |
| Sweet Potato | 33.2–75.9           | 1                        | 2.16–7.38     | 1               | 0.45–0.49   | 4           | 30,000   | 3       | 9 3     |
| Green Arrow Arum | -                   | -                        | -             | -               | -          | -           | 24,600   | 5       | 5 1 1   |
| Jerusalem Artichoke | 26.3               | 3                        | 2.7–2.9       | 2               | 0.4–0.8     | 2           | 37,070   | 2       | 9 3 3   |
| Hausa potato | -                   | -                        | -             | -               | -          | -           | 25,000   | 4       | 5 1 1   |
| Rhubarb | -                    | -                        | -             | -               | -          | -           | 11,200   | 4       | 4 3 3   |
| Fig-leaved Gourd | -                   | -                        | -             | -               | 0.47–0.52   | 1           | 50,000   | 1       | 2 2 2   |
| Watercress | -                   | -                        | -             | -               | -          | -           | 50,000   | 1       | 1 1 1   |
| Endive | 4.83                 | 1                        | 1.9–2.6       | 1               | -          | -           | 12,000   | 3       | 5 4 4   |

1 UC = Underutilised Crop.
3.3.6. Production Knowledge

The duration from sowing to harvesting was also used as a parameter to rank both staple crops and UCs. The priority was given for crops with a shorter harvesting period (Table 8). According to approximate harvest time, teff, cowpea, Jerusalem artichoke, and rhubarb ranked top in each crop category.

Table 8. Ranking of major and underutilised crops (UCs) based on the length of the growth period/production.

| Crop                     | Approximate Harvest Time (Days after Planting) | Rank All Crops | Rank UC ¹ |
|--------------------------|-----------------------------------------------|----------------|-----------|
| **Cereals and Pseudocereals** |                                              |                |           |
| Paddy                    | 145 days                                      | 8              |           |
| Maize                     | 70–200 days                                   | 3              |           |
| Common Wheat             | 115 days                                      | 7              |           |
| Sorghum                  | 3–7 months (=110–210 days)                    | 6              |           |
| Foxtail Millet           | 75–90 days                                    | 4              | 3         |
| Canihua                  | 95–150 days                                   | 5              | 4         |
| Teff                     | 2–5 months (=30–150 days)                    | 1              | 1         |
| Proso Millet             | 60–90 days                                    | 2              | 2         |
| **Legumes**              |                                              |                |           |
| Soybean                  | 65–200 days                                   | 2              |           |
| Chickpea                 | 3–6 months (=90–180 days)                    | 3              |           |
| Faba Bean                | 90–220 days                                   | 5              | 3         |
| Bambara groundnut        | 90–180 days                                   | 3              | 2         |
| Cowpea                   | 45 days                                       | 1              | 1         |
| **Starchy roots/tubers** |                                              |                |           |
| Potato                   | 272 days                                      | 4              |           |
| Sweet Potato             | 130–150 days                                  | 2              | 2         |
| Green Arrow Arum         |                                              |                |           |
| Jerusalem Artichoke      | 130 days                                      | 1              | 1         |
| Hausa potato             | 150–200 days                                  | 3              | 3         |
| **Vegetables**           |                                              |                |           |
| Rhubarb                  | after about 1 month (=90 days)               | 1              | 1         |
| Fig-leaved Gourd         | 3 month (=90 days)                            | 4              | 4         |
| Watercress               | 30–45 days                                    | 2              | 2         |
| Endive                   | 80–90 days                                    | 3              | 3         |

¹ UC = Underutilised Crop.

3.3.7. Production and Economic Data

The statistical database of Food and Agriculture Organization (FAOSTAT—http://www.fao.org/faostat/en/, accessed on 9 March 2020) contains country-level production and market information for a wide range of crops and products. Being less popular UCs, production and market information for most of the crops studied here was not available. Therefore, the production and economic category was omitted in the final rank summation index.

3.3.8. Final Rank

The ranks of all the categories were summed and ranked again to obtain the final ranking based on the RSI (Table 9). According to the RSI, teff (Eragrostis tef) ranked top among cereals and pseudocereals, while both faba bean (Vicia faba) and cowpea (Vigna unguiculata) ranked top among underutilised legumes. Both green arrow arum (Peltandra virginica) and Jerusalem artichoke (Helianthus tuberosus) were ranked 1st in the starchy roots/tubers category. The highest-ranked vegetables were fig-leaved gourd (Cucurbita ficifolia) and watercress (Nasturtium officinale).
Table 9. Ranking of UCs based on the rank summation index.

| Crop                         | Nutrition | Adaptive Traits | Other Uses | Germplasm | Physiology | Production Knowledge | Score | Rank UC |
|------------------------------|-----------|-----------------|------------|-----------|------------|----------------------|-------|---------|
| Paddy                        | 8         | 6               | 1          | 5         | 8          | 28                   |       |         |
| Maize                        | 6         | 1               | 2          | 4         | 3          | 16                   |       |         |
| Common Wheat                 | 2         | 6               | 2          | 2         | 7          | 19                   |       |         |
| Sorghum                      | 4         | 5               | 2          | 1         | 6          | 18                   |       |         |
| Foxtail Millet               | 6         | 6               | 5          | 2         | 7          | 4                    | 30    | 4       |
| Canihua                      | 2         | 2               | 7          | 4         | 3          | 5                    | 23    | 2       |
| Teff                         | 1         | 2               | 8          | 1         | 6          | 1                    | 19    | 1       |
| Proso Millet                 | 5         | 2               | 5          | 3         | 7          | 2                    | 24    | 3       |
| Soybean                      | 1         | 4               | 1          | 3         | 2          | 11                   |       |         |
| Chickpea                     | 3         | 4               | 2          | 1         | 3          | 13                   |       |         |
| Faba Bean                    | 2         | 2               | 2          | 3         | 2          | 5                    | 16    | 1       |
| Bambara groundnut            | 4         | 1               | 5          | 1         | 4          | 3                    | 18    | 3       |
| Cowpea                       | 4         | 2               | 2          | 2         | 5          | 1                    | 16    | 1       |
| Potato                       | 2         | 3               | 1          | 3         | 4          | 13                   |       |         |
| Sweet Potato                 | 5         | 4               | 3          | 3         | 2          | 17                   |       |         |
| Green Arrow Arum             | 1         | 2               | 4          | 2         | 1          | 10                   | 1     |         |
| Jerusalem Artichoke          | 3         | 1               | 1          | 3         | 1          | 10                   | 1     |         |
| Hausa potato                 | 3         | 4               | 4          | 2         | 1          | 17                   | 3     |         |
| Rhubarb                      | 4         | 1               | 1          | 4         | 4          | 1                    | 15    | 4       |
| Fig-leaved Gourd             | 2         | 1               | 1          | 2         | 1          | 4                    | 11    | 1       |
| Watercress                   | 1         | 4               | 1          | 2         | 1          | 11                   | 1     |         |
| Endive                       | 3         | 3               | 1          | 3         | 3          | 14                   | 3     |         |

1 UC = Underutilised crop.

4. Discussion

Food and nutrition security is a global challenge. Ending all forms of malnutrition by the end of the year 2030 is one of the targets of the United Nations sustainable development goals (SDG #2 Zero Hunger). Crop diversification, particularly using neglected and underutilised crops, is an ideal solution for eradicating malnutrition [5,36]. This is because the dependency on a few key crops/staple crops has been identified as a major barrier to dietary diversity and cause of malnutrition [36]. In this regard, this article outlined a “systematic approach” that can be adopted for the identification of UCs across Italy. Using this approach, a list of high-potential UCs that can specifically be adapted for Italy are identified.

Figure 4 shows a downward trend for available agricultural lands. As land resources become scarce in Italy, efforts to develop high-potential crops are needed. In this regard, investment in the knowledge system [7] such as the one that is discussed in this article will help with the following:

1- Proposals for funding are backed by current evidence and data;
2- Risk reduction by developing alternative plans;
3- Answering ‘what if’ questions regarding the future of agriculture and environment.
Despite technical advancements, food and nutritional security and sustainability have not been achieved throughout the world in an equitable manner [37]. Therefore, diversification of the farming system and food basket are ideal solutions to the problem [38]. UCs have been identified as alternative crops for food and nutritional security and sustainability in many parts of the world [5,38,39]. Therefore, a priority was given to nutrition security in crop selection. To make it sustainable, several features other than food sources were used to select the best UCs. This is because one of the prominent features of UCs is the adaptability to a wider range of biotic and abiotic stresses [39–42], which can make them become future crops [43]. Crop species with adaptive traits are useful in breeding to improve agroecosystem resilience [44] and, indirectly, farm revenue [17]. Figure 5 shows the suggested reproducible ‘pipeline’ for developing evidence bases for agricultural diversification.

Since it does not need field experimental data or local knowledge, agro-ecological suitability analysis allows the assessment of wide range of crops over a large area [45]. The site-specificity of field experiments hampers temporal and spatial analysis from a wide perspective [46]. However, crop management (plant density, agrochemical application, irrigation) and production details cannot be recommended and assessed using the approach followed in this paper. The selection of suitable crops based on climate suitability and different types of favourable characteristics was the initial step in the selection of UCs. Once the potential crops are selected based on the suitability analysis, yield estimation (using crop modelling) and detailed field experiments are necessary before commercial cultivation.

One of the major drawbacks of selection of underutilised crops in different agro-ecological zones through the suitability assessment and yield prediction of underutilised crops is the lack of evaluation frameworks and models. However, with the growing concern in relation to neglected and underutilized crops, dedicated land evaluation frameworks and protocols [8,47,48] and crop models/modelling approaches [38,39,49,50] which show
potential have been carried out in the recent past. Other than the method used here for crop selection, different approaches/frameworks as mentioned above can be tested to select the most suitable crops. A separate article will describe the yield forecasting of one of the selected underutilised crops using a crop modelling approach.

Published information on some of the crops which were selected in this study are already available in Italy, which shows that there is potential. For example, quality trait and yield response, ecological benefit, agronomic, and other information on faba bean are reported in Italy [51–53]. Even though the initial literature review in the Scopus database yielded a lower number of articles, there are several other articles that may have been indexed in other databases and available in other languages. Therefore, it is essential to perform a detailed literature review/systematic review to identify the available information on underutilised crops.

More attention should be paid to breeding, agronomic research, and value addition to popularise these crops in Italy. It is also important to study where in Italy would be most suitable for each high-potential underutilised crop, and their potential yields and economic returns. Lessons learned from other EU countries that show evidence of uneven distribution of agricultural development funds should be considered for Italy [54,55]. In particular, in terms of available funds, the impact of regional and continental investment on similar projects should be studied before making further cases for the development of new crops. Ample planning is required to ensure that the funds that are allocated for the development of the research value chain (RVCs) of UCs are utilised properly, and that a knowledge system approach [37] is adopted for the development of UCs in Italy. In this regard, projects such as LandSupport [56] can help with increasing confidence and awareness about alternative land uses.

5. Conclusions

An increasing number of studies show the vulnerability of food systems in Italy. This article presents a systematic approach to the selection of currently neglected and underutilised crops that could be the key to future sustainability of agriculture in Italy and elsewhere. A novel crop shortlisting framework based on (1) agro-ecological shortlisting and (2) rank summation index was performed across Italy in order to develop a priority list of crops that can help achieve food and nutritional security and sustainability. Out of the 2700 crops, 7 high-ranking crops from 4 categories were selected: teff (*Eragrostis tef*) from cereals and pseudocereals, faba bean (*Vicia faba*) and cowpea (*Vigna unguiculata*) from legumes, green arrow arum (*Peltandra virginica*) and Jerusalem artichoke (*Helianthus tuberosus*) from starchy roots/tubers, and fig-leaved gourd (*Cucurbita ficifolia*) and watercress (*Nasturtium officinale*) from vegetables. The crop selection approach used in this study can be used to diversify the food systems in Italy or elsewhere, using data collected from different sources.

The next step is to develop detailed climate and soil suitability assessments using local data, yield forecasting, and economic analysis. As more and more evidence and data appear in peer-reviewed literature on UCs, it is important to be able to automate the processes described in this article for the benefit of three groups of users: (1) researchers, (2) regulatory agencies, and (3) the public. Data can be mined automatically and used for automatic analysis along with other information from local, regional, and national data.

Advancement in environmental datasets such as for climate and soil will help improve the results reported this article. The evidence shows that the list of high-potential but neglected crops could be much larger; therefore, investment in knowledge systems and data infrastructures that can provide more options in terms of useful species for agriculture are required. It is also obligatory for all stakeholders in agriculture to promote new approaches in the development of alternative land uses, and therefore, with this article, the authors hope to trigger more discussion surrounding the inclusion of UCs in rural development plans using data-driven approaches.
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Appendix A

Table A1. Ranking of major and underutilised crops (UCs) based on macronutrient composition.

| Crop               | Carbohydrate | Protein | Rank Sum | Rank UC |
|--------------------|--------------|---------|----------|---------|
|                    | Value (g/100 g Dry Matter) | Rank | Value (g/100 g Dry Matter) | Rank | Rank All Crops | Rank UC |
| Cereals and Pseudocereals |              |        |          |        |                 |        |
| Paddy              | 76.25        | 1      | 7.54     | 8      | 9               | 5      |
| Maize              | 74.26        | 4      | 9.42     | 7      | 11              | 6      |
| Common Wheat       | 75.90        | 2      | 11.31    | 3      | 5               | 1      |
| Sorghum            | 74.60        | 3      | 13.30    | 1      | 8               | 4      |
| Foxtail Millet     | 63.20        | 8      | 11.20    | 5      | 13              | 8      |
| Canihua            | 65.52        | 7      | 13.79    | 2      | 7               | 2      |
| Teff               | 73.13        | 5      | 13.30    | 2      | 7               | 2      |
| Proso Millet       | 72.85        | 6      | 11.02    | 6      | 12              | 7      |
| Legumes            |              |        |          |        |                 |        |
| Soybean            | 74.8         | 1      | 36.00    | 1      | 2               | 1      |
| Chickpea           | 35.00        | 5      | 20.47    | 4      | 9               | 5      |
| Faba Bean          | 41.00        | 4      | 26.12    | 2      | 6               | 3      |
| Bambara groundnut  | 58.29        | 2      | 21.46    | 3      | 5               | 2      |
| Cowpea             | 54.73        | 3      | 2.60     | 5      | 8               | 4      |
| Starchy roots/tubers|              |        |          |        |                 |        |
| Potato             | 83.21        | 2      | 10.34    | 3      | 4               | 1      |
| Sweet Potato       | 78.40        | 3      | 5.30     | 4      | 7               | 4      |
| Green Arrow Arum   | 74.00        | 5      | 17.90    | 1      | 6               | 2      |
| Jerusalem Artichoke| 74.57        | 4      | 7.60     | 3      | 7               | 4      |
| Hausa potato       | 86.70        | 1      | 5.00     | 5      | 6               | 2      |
| Vegetables         |              |        |          |        |                 |        |
| Rhubarb            | 4.54         | 3      | 0.90     | 3      | 6               | 3      |
| Fig-leaved Gourd   | 70.17        | 1      | 0.40     | 4      | 5               | 2      |
| Watercress         | 31.70        | 2      | 33.8     | 1      | 3               | 1      |
| Endive             | 3.35         | 4      | 1.25     | 2      | 6               | 3      |
Table A2. Ranking of major and underutilised crops (UCs) based on vitamin composition.

| Crop            | Value (µg/100 g dm) | Rank  | Value (µg/100 g dm) | Rank  | Value (µg/100 g dm) | Rank  | Value (µg/100 g dm) | Rank  | Rank Sum  | Rank All Crops | Rank UC |
|-----------------|---------------------|-------|---------------------|-------|---------------------|-------|---------------------|-------|-----------|----------------|---------|
| Paddy           | 0                   | 2     | 0.07                | 8     | 0.05                | 8     | 1.6                 | 7     | 0         | 2              | 27      |
| Maize           | 11                  | 1     | 0.385               | 6     | 0.201               | 4     | 3.627               | 4     | 0         | 2              | 17      |
| Common Wheat    | 0                   | 2     | 0.387               | 5     | 0.108               | 5     | 4.381               | 2     | 0         | 2              | 16      |
| Sorghum         | 0                   | 2     | 0.33                | 7     | 0.1                 | 7     | 3.69                | 3     | 0         | 2              | 21      |
| Foxtail Millet  | 0                   | 2     | 0.6                 | 2     | 0.1                 | 6     | 3.2                 | 6     | 0         | 2              | 18      |
| Canihua         | 0                   | 2     | 0.78                | 1     | 0.55                | 1     | 1.34                | 8     | 0         | 2              | 14      |
| Teff            | 0                   | 2     | 0.39                | 4     | 0.27                | 3     | 3.36                | 5     | 88        | 1              | 15      |
| Proso Millet    | 0                   | 2     | 0.42                | 3     | 0.29                | 2     | 4.72                | 1     | 0         | 2              | 10      |
| Soybean         | 9                   | 3     | 0.435               | 3     | 0.175               | 4     | 1.65                | 2     | 6         | 1              | 13      |
| Chickpea        | 3                   | 4     | 0.48                | 2     | 0.21                | 2     | 1.54                | 3     | 4         | 2              | 13      |
| Faba Bean       | 3                   | 4     | 0.555               | 1     | 0.333               | 1     | 2.832               | 1     | 1.4       | 4              | 11      |
| Bambara groundnut | 26.05             | 1     | 0.3                 | 4     | 0.2                 | 3     | 1.3                 | 5     | 1.17      | 5              | 18      |
| Cowpea          | 41                  | 2     | 0.11                | 5     | 0.15                | 5     | 1.45                | 4     | 2.5       | 3              | 19      |
| Potato          | 0                   | 3     | 0.081               | 2     | 0.032               | 3     | 1.063               | 2     | 19.7      | 1              | 11      |
| Sweet Potato    | 709                 | 1     | 0.08                | 3     | 0.06                | 1     | 0.56                | 4     | 2.4       | 3              | 12      |
| Green Arrow Arum | 640                | 0     |                     |       |                     |       |                     |       |           |                |         |
| Jerusalem Artichoke | 1          | 2     | 0.2                 | 1     | 0.06                | 1     | 1.3                 | 1     | 4         | 2              | 7       |
| Hausa potato    | 56                  | 5     | 0.05                | 4     | 0.02                | 4     | 1                   | 3     | 1         | 4              | 15      |
| Rhubarb         | 5                   | 3     | 0.02                | 4     | 0.03                | 3     | 0.3                 | 3     | 8         | 3              | 16      |
| Fig-leaved Gourd | 105                | 1     | 0.15                | 3     | 0.05                | 1     | 0.85                | 1     | 13.5      | 1              | 6       |
| Watercress      | 160                 | 1     | 0.09                | 2     | 0.12                | 1     | 0.2                 | 4     | 13        | 2              | 10      |
| Endive          | 108                 | 2     | 0.08                | 3     | 0.075               | 2     | 0.4                 | 2     | 6.5       | 4              | 13      |

Table A3. Ranking of major and underutilised crops (UCs) based on mineral content.

| Crop            | Value (mg/100 g dm) | Rank  | Value (mg/100 g dm) | Rank  | Value (mg/100 g dm) | Rank  |
|-----------------|---------------------|-------|---------------------|-------|---------------------|-------|
| Paddy           | 9                   | 6     | 0.80                | 8     | 108                 | 8     |
| Maize           | 7                   | 8     | 2.71                | 7     | 210                 | 7     |
| Common Wheat    | 32                  | 3     | 4.56                | 3     | 355                 | 3     |
| Sorghum         | 13                  | 5     | 3.36                | 4     | 289                 | 5     |
| Foxtail Millet  | 31                  | 4     | 2.80                | 6     | 290                 | 4     |
| Canihua         | 110                 | 2     | 15.00               | 1     | 375                 | 2     |
| Teff            | 180                 | 1     | 7.63                | 2     | 429                 | 1     |
| Proso Millet    | 8                   | 7     | 3.01                | 5     | 285                 | 6     |
| Soybean         | 197                 | 2     | 3.55                | 4     | 194                 | 4     |
| Chickpea        | 57                  | 5     | 4.31                | 3     | 252                 | 2     |
| Faba Bean       | 103                 | 4     | 6.70                | 2     | 421                 | 1     |
| Bambara groundnut | 0.13             | 6     | 0.44                | 6     | 5.28                | 6     |
| Cowpea          | 126                 | 3     | 1.10                | 5     | 53                  | 5     |
| Potato          | 12                  | 4     | 0.81                | 3     | 57                  | 3     |
| Sweet Potato    | 30                  | 2     | 0.61                | 4     | 47                  | 4     |
| Green Arrow Arum | 140                | 3     | 3.40                | 1     | 78                  | 2     |
| Jerusalem Artichoke | 14        | 3     | 3.40                | 1     | 78                  | 2     |
| Hausa potato    | 70.4                | 1     | 2.41                | 2     | 100.32              | 1     |
| Rhubarb         | 86                  | 1     | 0.22                | 4     | 14                  | 4     |
| Fig-leaved Gourd | 31                 | 4     | 7.00                | 1     | 29.5                | 3     |
| Watercress      | 65.6                | 2     | 7.00                | 1     | 60                  | 1     |
| Endive          | 52                  | 3     | 0.83                | 3     | 28                  | 2     |
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