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**Underutilized crops and their economic potential:**

**A review**

BACHELOR'S THESIS

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# Declaration

I hereby declare that I have done this thesis entitled Underutilized crops and their economic potential: A review independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, 19<sup>th</sup> of April 2018

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Barbora Motýlová

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## **Abstract**

World food supply depends on only few major crops and only three of them - corn, rice and wheat, are making over half of it. But there are about 7000 crop species which are fully or at least partly domesticated and used for food. Those other minor crops in scientific literature are mostly called Neglected and Underutilized plant Species (NUS). Thus, the aim of the thesis was to use Web of Science (WoS) database to analyse so far written literature dealing with NUS. Using WoS toolkits and scientometric approach, total number of results were identified and analysed. Special attention was given to economically-oriented ones, which were further summarized via SWOT analysis. Results show that NUS could bring many benefits like higher nutritional value or climate change resilience, and higher crop diversity and their adaptability for poor soils and drought is making them important for future food security. However, despite all those benefits, NUS still do not receive adequate attention from researchers or development institutions. But it is also necessary to be aware of problems which may appear when underutilized crop will become highly used cash crop. We can mention case of quinoa in Peru. The new popularity of quinoa increased production, pushed out other traditional crops and also price of quinoa is higher than ever before. Furthermore, farmers are also struggling with weak or no seeds supplies, laborious processing, disappearing of traditional knowledge or policy frameworks to reach markets. By pointing out benefits, good promotion and better processing methods may make NUS be more marketable. And higher marketability of product may increase production of underutilized crops. Other motivation may be agritourism or payments for ecosystem services.

**Key words:** minor crops, neglected plants, value chain, market potential, food security

## Abstrakt

Světová nabídka potravin závisí na několika málo hlavních plodinách a pouhé tři z nich – kukuřice, rýže a pšenice zajišťují přes polovinu. Existuje ale kolem 7000 plodin, které jsou plně, nebo alespoň částečně domestikovány a používány k jídlu. Tyto minoritní plodiny se ve vědecké literatuře většinou nazývají opomíjené a podužívané. Cílem práce bylo s použitím Web of Science databáze analyzovat dosud napsanou literaturu o opomíjených rostlinách. Pomocí nástrojů Web of Science a scientometrického postupu byl identifikován a analyzován celkový počet výsledků. Zvláštní pozornost byla věnována ekonomicky orientovaným výsledkům, které byly dale shrnuty pomocí SWOT analýzy. Výsledky ukazují, že opomíjené plodiny mají mnoho benefitů jako vyšší nutriční hodnoty či odolnost vůči změně klimatu a vyšší rozmanitost plodin i jejich přizpůsobivost na chudé půdy je dělá důležitými pro budoucnost potravinové bezpečnosti. Přes tyto všechny benefity, podužívané plodiny stále nedostávají dostatečnou pozornost ze strany vědců ani rozvojových institucí. Je ale také nezbytné si uvědomit problémy, které se mohou objevit když se podužívaná plodina stane nadužívanou plodinou pro zisk. Můžeme zmínit případ quinoy v Peru. Nová popularita quinoy zvýšila její produkci a vytlačila ostatní tradiční plodiny, I cena quinoy je nyní vyšší než kdy předtím. Farmáři navíc čelí problémům jako slabá nebo žádná nabídka semen, pracné zpracování plodin, ubývání tradičních vědomostí a nebo mají problémy při dostávání se na trh. Poukazováním na benefity, dobrou propagací a lepšími metodami zpracování mohou být podužívané plodiny více prodavatelné. Vyšší prodejnost produktu může zvýšit produkci podužívaných plodin. Další motivací může být i agroturismus nebo placení za ekosystémové služby.

**Klíčová slova:** minoritní plodiny, opomíjené rostliny, hodnotový řetězec, tržní potenciál, potravinová bezpečnost

## **List of the abbreviations used in the thesis**

NUS Neglected and Underutilized plant Species

WoS Web of Science

PES Payment for Ecosystem Services

ALV African Leafy Vegetable

R&D projects Research and Development projects

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# 1. Introduction

Today modern agriculture is focused only on a few staple crops and only three major crops – wheat, maize and rice are providing half of the world population's carbohydrates, proteins and calorie requirements. And furthermore, less than 30 varieties of crops are used for meeting 95 % of human nutritional needs. Even though there are about 7000 plant species in the world known to be used for food, only six crops are covering over half of the world's arable land. We can see the surface coverage of those six plants over a million hectares (wheat, soybean, maize, rice, barley and rapeseed) in figure 1 (see e.g. Jacobsen et al. 2015; Hughes 2009).

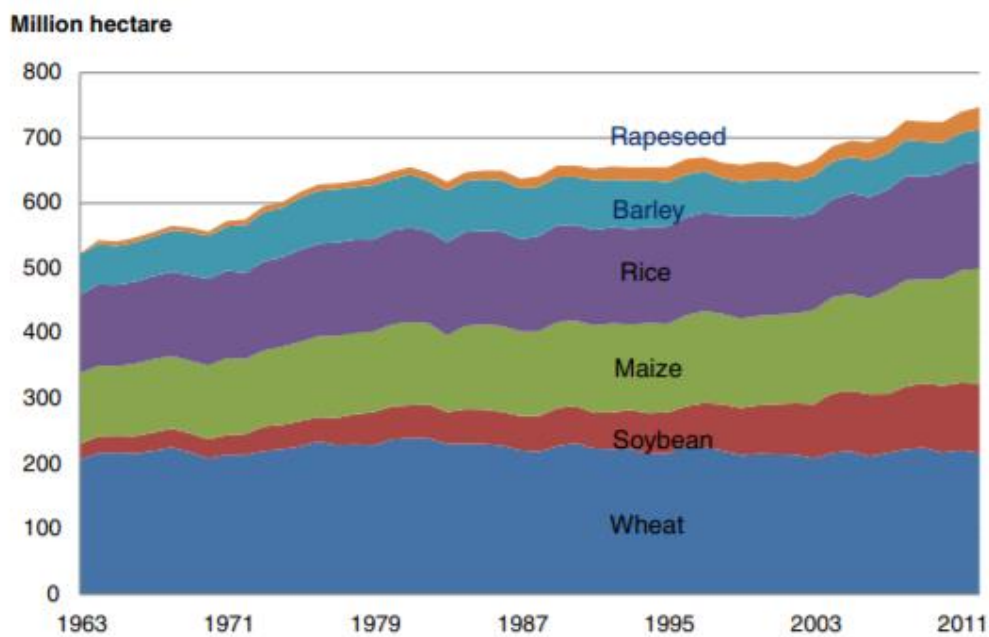


Fig. 1 Development of global arable area with six major crops (1963-2012), based on  
FAO statistics

source: Jacobsen et al. 2015

For those other, not so intensively grown crops, there is wide range of terms like orphan, traditional, abandoned, lost, forgotten, promising, niche, underdeveloped,



alternative, underexploited etc. but in scientific literature is most common to call these plants “underutilized” and in this thesis they will be called Neglected and Underutilized plant Species, shortly NUS.

There is not even clear definition on what they are, but we can conclude that often they have strong links to their cultural heritage and place of origin. Also, they tend to be well adapted for marginal lands and agro-ecological niches, may be collected in the wild, can be highly nutritious or have medical properties, and have only little attention from research, farmers, policy-makers, decision-makers, donors, technology providers and consumers (Hoeschle-Zeledon 2007).

Some species may be underutilized in some regions, but in other geographical zones they are found to be commonplace. For example, breadfruit (*Artocarpus altilis*) found in Pacific countries and Caribbean Islands is an important component for sustainable livelihoods, playing a key role in local diets and having a significant economic impact. But in African countries like Nigeria this crop is largely underutilized, even though it may be a valuable asset to increasing food production and household income security (Omobuwajo 2007).

When we find talk of NUS as “minor” it is in situations where we compare their production and market value compared with other major crops. Often it is in purely economic terms that these NUS seen as having minor importance. Such situations have many causes. A huge decline in number of local and traditional crop species is linked to Green Revolution. They have been replaced by high-yielding crop cultivars which were developed in modern breeding programs. The traditional crops are not meeting modern standards for uniformity, high yields and other appreciated characteristics, which are useful for easier cultivation, harvest and speedy financial turnover. Therefore, NUS may be less competitive on global markets compared to high-yielding bred commercial cultivars. Other additional reasons for the shrinking number of species can be seen in agricultural intensification and simplification, processes that based on advantages for growing in wider range of habitats, simple cultivation requirements, easier processing,

longer storability, nutritional properties, palatability and so on, the food industry favours some crops instead of others (see e.g. Padulosi et al. 2002; Giuliani et al. 2004; Ebert 2014).

Though the major crops have high rate in production volume and other characteristics, the neglected indigenous crops can be seen excelling in environmental adaptability, requiring low inputs and content of protein, minerals, vitamins and other nutrition values. All of which may help with the reduction of malnutrition, including problem of “hidden hunger”. Underutilized indigenous food crops are nowadays receiving wider attention by farmers, consumers and researchers, and not only due to awareness of their nutritional value. Other benefits of those marginally-used species come with their low input requirements, as well as helping to reduce the environmental degradation caused by extreme weather conditions and natural disasters (Hughes 2009).

This bachelor thesis should also serve as brief summary and introductory overview about NUS, as well as presenting scientific and cultural knowledge about NUS. It is my hope that this thesis can help stimulate further scientific research into this insufficiently explored topic.

## **2. Aims of the Thesis**

The main purpose of this thesis was to analyse scientific literature related to the topic of underutilized, neglected and niche crops from a chosen database. The aim was to find out what has been previously written about NUS, analyse this literature and discover the most common and discussed topics related to NUS, whilst identifying categories of literature on the subject. Additionally, another goal of this thesis was to point out the benefits of traditional crops, and to reveal their importance for future agriculture. Based on thus-far published literature dealing with economic issues, this thesis summarized the main information about NUS. The goal was not only to show the positive side and benefits of NUS, but also to critically evaluate the weak points and problems which may appear with increased production of NUS and their introduction into market supply. The aim of this thesis is not to make in-depth research solely on one subject, but to discuss all significant factors mentioned in identified literature, as well as to evaluate as many points as possible that may be connected to NUS and particularly with their marketing and production.

### 3. Methods

To be successful in the quantitative analysis of scientific literature, accurate sources of citation data must be used. In this case, Web of Science, previously known as Web of Knowledge was chosen. In the past the specialised database Web of Science (WoS), was the major source of citations. Main reason for choosing this database was its wide history, reliability and use by main research institutions as well as donors and/or implementers of R&D projects (Mingers & Leydesdorff 2015).

The aim of thesis was to uncover available articles about underutilized or neglected plants. There are many synonyms for underutilized plants, but for this search was chosen only adjective words underutilized, neglected and niche. As nouns were used with words such as crop and plant in singular and plural form. To help with this task Boolean operators were used and undertook search queries such was: "underutilized crop" OR "underutilized crops" OR "neglected crop" OR "neglected crops" OR "underutilized plant" OR "underutilized plants" OR "neglected plant" OR "neglected plants" OR "niche plant" OR "niche plants" OR "niche crop" OR "niche crops".

Found results were entered to Microsoft Excel. Collected data included the name of the article, the journal it appeared in, the year of its publication, Author KeyWords, KeyWords Plus, publisher, research areas, Web of Science categories, document type and abstract. Found articles not related to topic of NUS were deleted. Submitting data into Microsoft Excel made it easier to compile information and to create graphs.

Four of the most-often cited articles were mentioned first, followed by the most cited articles from the last five and three years to see which actual results are the most cited (Mingers & Leydesdorff 2015). Number of citation was up until the date of the 3<sup>rd</sup> of April 2018. Graphs with articles recorded by year were also made. Another step in the process was discovering contributions by article categories. In analysing categories and classification of scientific literature, only articles as a document type were selected. Articles were classified into those categories according to Name of article, Author

KeyWords, KeyWords Plus, Research Areas, Web of Science Categories and abstract. Most of articles belong to more than one category. For better visual representation a pie graph was made from this data.

For the second part of the thesis, articles were chosen according to their relationship to the economics aspects. The economic-based literature was picked out from all the previous search results, which was done by selecting literature including key words; Market, Value Chain, Household Income, Economy, Economic and Rural Communities. Results not related to economy were removed. From those results the information related to NUS as a product were collected, as well information related to the marketing and/or cultivating of NUS. Those main points were divided into four parts – strengths, weaknesses, opportunities and threats using SWOT analysis.

In this thesis was not investigated whether the various species of plant are considered neglected or not. Every plant that is referred to as a neglected/ underutilized/ niche plant in chosen literature was considered as NUS.

## **4. Results and Discussion**

A total number of 318 articles were identified on Web of Science database via using key words “underutilized”, “neglected” and “niche” combined with the words “plant” and “crop” in singular and also plural form. Out of those 318 results 11 were not relevant to topic of Underutilized and Neglected Species (NUS). Those 11 articles appeared as results because in abstract the key words were next to each other, even though it had a different context than the one intended. In another case one sentence in abstract ends with word “neglected”, and the word “plant” is first word of another sentence. By this coincidence this was another article which was found during searching articles about NUS. There was also another article where plant was used in the context of a factory. After removing those 11 false articles the final number of articles found on Web of Science about NUS is 307.

### **4.1. Most cited results**

As we can see at figure 2, out of the total number of results, 98 of them were not even once cited (32%). Most of the articles were cited ten times or less. More than 10 times were cited 57 articles and only 4 results have been cited more than 50 times.

The most cited result was “Physicochemical and functional properties of tropical tuber starches: A review”, published in *Starch-starke* journal in 2002. The total number of citations is 196. This review is focused on the neglected tropical tubers cassava and the sweet potato. Among tropical tubers only those two are used for industrial applications, because it is difficult to extract pure starches from the others. The research area of this article is Food Science and Technology.

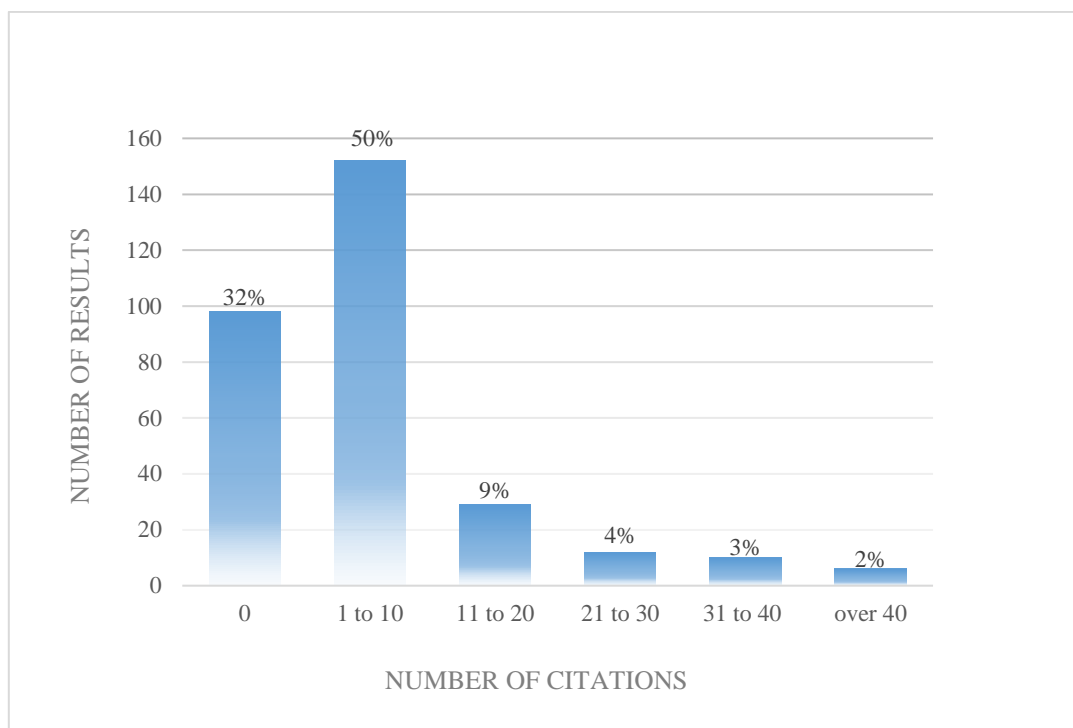


Fig. 2 Distribution of scientific results according to number of citation

The second result, ranked by the number of citations, is the article entitled “Production of biodiesel from high free fatty acid Karanja (*Pongamia pinnata*) oil” published in journal Biomass and energy. This article, published in April 2008 was cited 179 times. The third result is a review “Simple Sequence Repeat Polymorphisms (SSRPs) for Evaluation of Molecular Diversity and Germplasm Classification of Minor Crops” which was cited 63 times. This paper from November 2009 published in Molecules journal is examining minor crops from molecular perspective and genetic diversity. The fourth highest result which was cited 59 times was “Industrial production, processing, and utilization of sago palm-derived products”. This review was published in April 2008 in the journal Carbohydrate Polymers and is discussing sago palm, which is gaining much more importance in recent times due to it being extremely sustainable and having ability to thrive in most soil conditions.

If we consider only results from last five years (2013-2018), the most cited literature is the agricultural orientated review “Feeding the world: genetically modified crops versus agricultural biodiversity” published in October 2013 in *Agronomy for sustainable development*. This paper pointing to the importance of agrobiodiversity and its impact on food security was cited 40 times. If we consider only results from last three years (2015-2018) the most cited article “GBS-SNP-CROP: a reference-optional pipeline for SNP discovery and plant germplasm characterization using variable length, paired-end genotyping-by-sequencing data” was cited 12 times.

## 4.2. Number of articles per year

From the chronological perspective, the oldest article found originates from the year 1968. However, since then and until 2000, almost no literature was published, mostly one or no article per year. However, since 2000 the number of scientific outcomes is seen to grow as we can see from figure 3. It shows that most results about NUS found on WoS were published in last seven years, particularly in 2016 (26 results), 2017 (21 results) and 2011 (19 results).

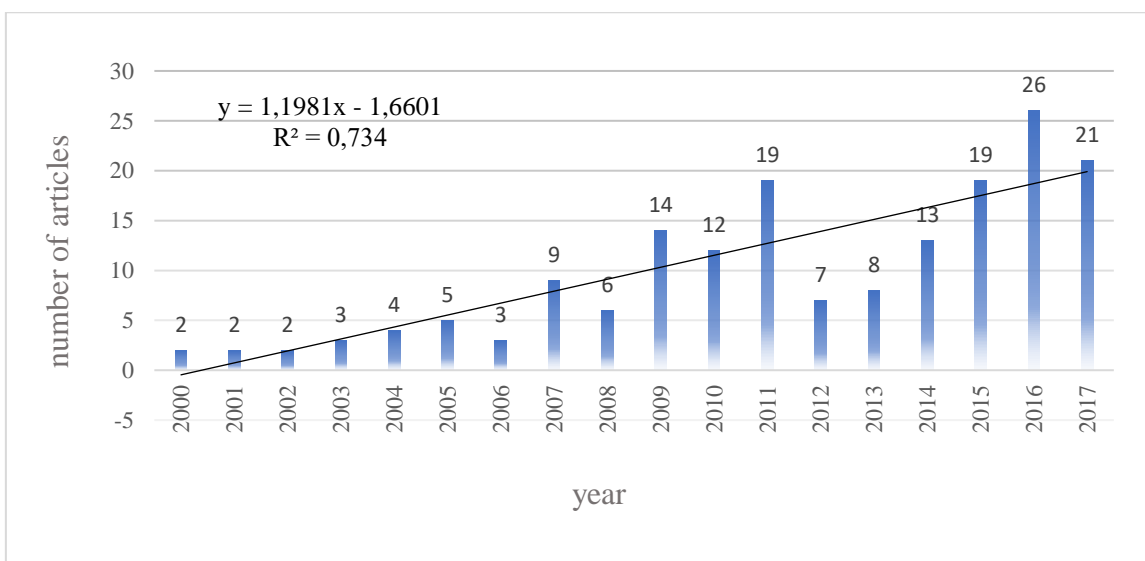


Fig. 3 Number of articles about NUS per year on WoS since year 2000



### **4.3. Journals, Publishers, and Document types**

When we consider our results, most of the journals featured only published literature related to NUS once or twice. The journals “Experimental Agriculture” and “Food chemistry and Sustainability” each published four of these results, the journal “Plos One” published five of them, whilst the journal which published the most results was the journal “Genetic Resources and Crop Evolution” with total number 41 of published results. Genetic Resources and Crop Evolution is an international journal covering topics related to plants genetic resources. All literature is written in English and is subject to peer review. This journal is available since 1953 and holds impact factor equal to 1.294 in 2016 (Springer, 2016).

The most published results were from the Belgian publisher International Society for Horticultural Science, a leading independent organization, focused on horticultural sciences having a total of 68 published results. In second place with 65 results was Springer Publishing, an American publishing company founded in year 1950 covering topics like nursing, gerontology, psychology, social work, counselling, public health and rehabilitation. Third biggest publisher in this case is Dutch company Elsevier, one of the major world’s source of scientific information which published 28 of results about NUS. Last publisher with significant number of results is Taylor & Francis Group with 16 published results. All other publishers had only a small amount of literature published about NUS.

As document type 175 of results were articles, 33 of them were a review, 85 results were classified as proceedings paper and 13 results belonged to other or more than one category.

#### 4.4. Classification of articles

NUS in scientific literature on WoS were mostly linked to their nutritional values, food security, medicine, drought resistance and adaptability to climate change, conservation, biodiversity, renewable energy sources, new materials, indigenous communities, rural households, traditional knowledge, as well as economic potential and marketing. Figure 4 shows the majors topics of found articles. Most of articles are targeting more fields, therefore they belong to more than one category.

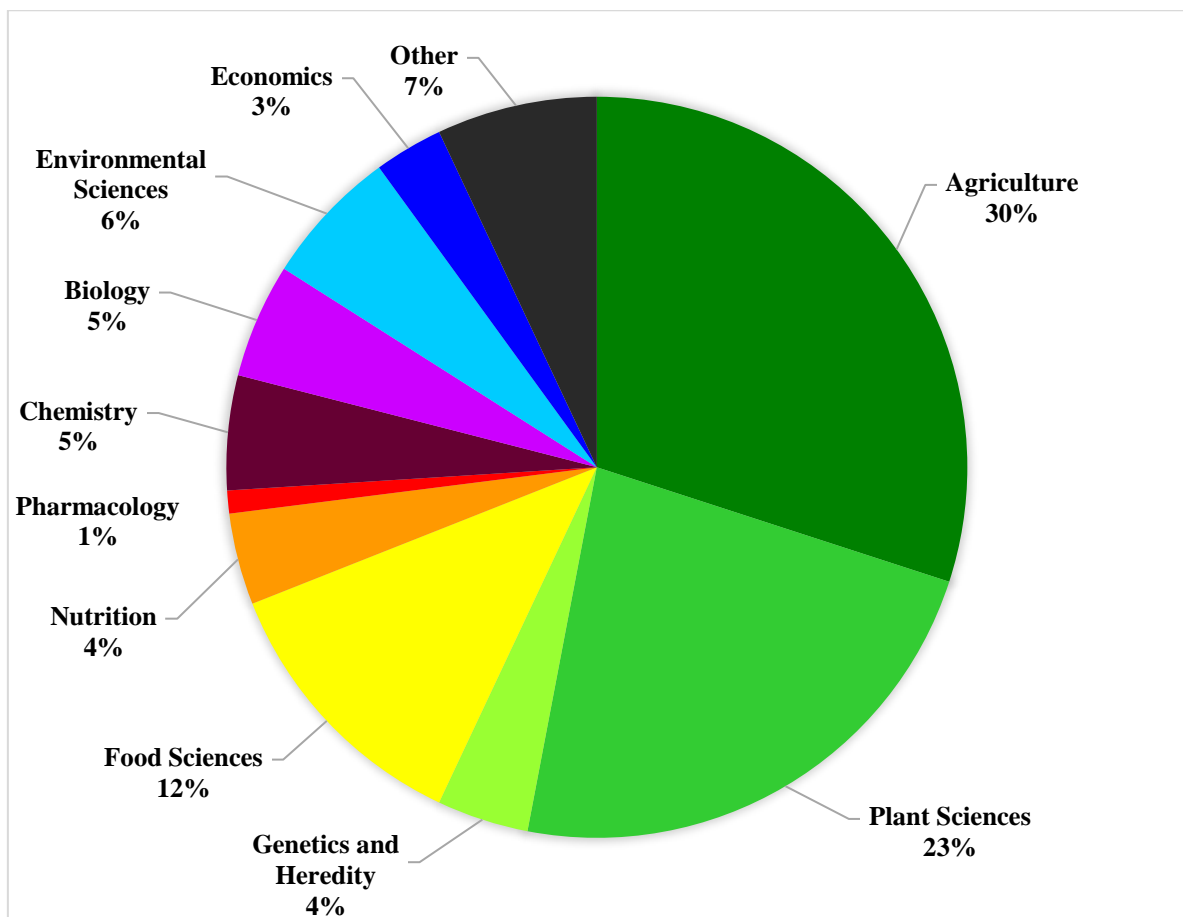


Fig. 4 Classification of identifies articles into pre-defined categories

The most common categories for articles about underutilized plants are Agriculture (30%) and Plant Sciences (23%), which are together comprise of more than half. Other

relevant topics are Food Sciences (14%) and Nutrition (4%). Due to its importance related to biodiversity and farming systems, Environmental Sciences are often discussed, these topics together making Environmental Science 6% of the findings. Global food production is growing and nowadays it faces many obstacles including a changing climate, that's why we see an increased interest in genetic resources because of breeding and mitigating loss in yield (Jacobsen et al. 2015), therefore the Genetics and Heredity category is also often discussed and appearing in 4% of found results. Both Biology and Chemistry are appearing in 5% of findings. Despite all benefits and potential which NUS have, as Economics we can only classify as 3% of articles, second smallest percentage after Pharmacology with 1%. There is also the remaining 7% of articles which are classified as a minor category, for reasons of only partial significance, which are together in category labelled "Other". This include categories as engineering, material science, technology, physical geography, dairy and animal science, soil science, toxicology etc.

## **4.5. SWOT analysis**

Results discussing economical topics were including wide range of information, to cover all points mentioned in literature and assemble it together the SWOT analysis was made.

### **4.5.1. Strengths**

NUS possess many strengths as a product, like low inputs required for cultivation, drought resilience, adaptability for poor soils, importance for household security or nutritional values. Main features discussed in literature were:

#### **Climate change resilience and adaptability for poor soils**

Despite the advanced agricultural technology of modern times; the creation of high yielding varieties of crops as well as precision sowing and fertilizing, much of our

present systems of crop cultivation rely on a climate which we cannot influence. The main drivers of crop growth are solar radiation, temperature and precipitation, which are all at the mercy of climate. Plant infections and diseases, floods and droughts, which are more often nowadays thanks to climate change, may have catastrophic consequences. Droughts in recent decades in Sahelian region of Africa had caused big decrease of production. In the American Midwest in 1988, a drought reduced production of U. S. corn by 30 % (costing U.S taxpayers 3 billion dollars). Fifty years before this, in the 1930s the yield of U. S. corn was reduced to 50 % by drought (Rosenzweig et al. 2001). In future we can apart from drought expect also increases in soil salinity due to climatic change. At the same time, it has been seen that some underutilized crops can have positive impact on mitigation of those problems. There are many examples of drought-tolerant crops, like Bambara groundnut (*Vigna subterranea*), nutritious African plant or wide range of millet family, small-seeded cereals. Another remarkable crops able to grow on marginal soil are drumstick tree (*Moringa oleifera*) from India, fruit custard apple (*Annona squamosa*), Indian gooseberry (*Phyllanthus emblica*), Indian jujube (*Zizyphus mauritania*), tamarind (*Tamatindus indica*) or neem (*Azadirachta indica*). Andean crops like cañahua (*Chenopodium pallidicaule*), quinoa (*Chenopodium quinoa*), amaranth (*Amaranth spp.*) and Andean lupine (*Lupinus mutabilis*) which are all remarkable for not only their drought resistance, but also frost and salinity tolerance (Jacobsen et al. 2015).

High-yielding varieties are effective because they can produce big amount of food on relatively small area, but problems arise as they work only in perfect conditions and high inputs. On the other side, traditional crops can produce food even with lower water availability and lower inputs, as we can see on figure 5.

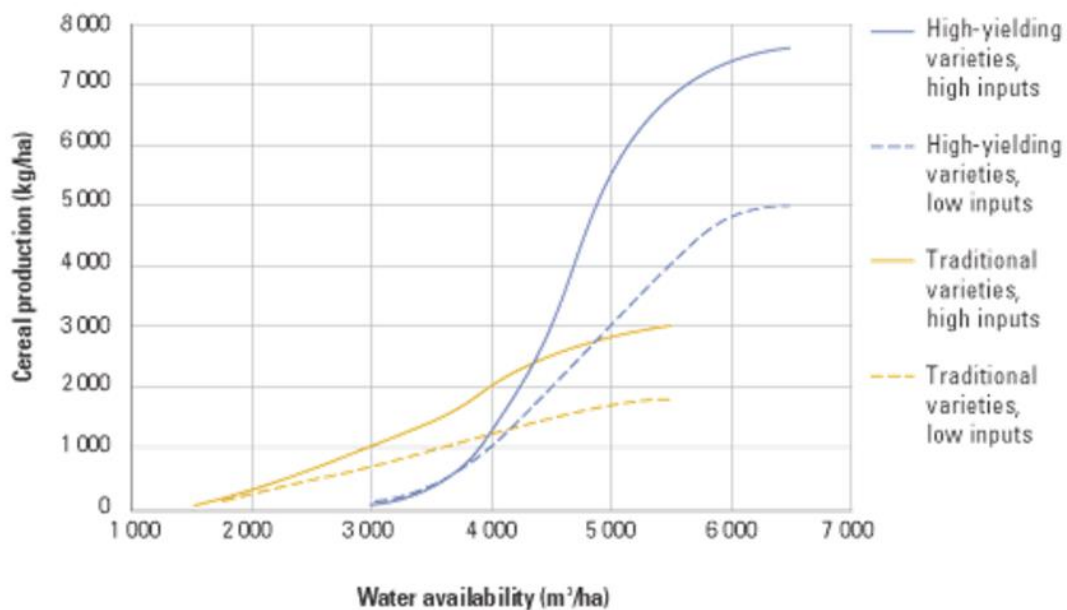


Fig. 5 Yield response of crops to water availability, source: FAO 2003

In this graph showing cereal production (kg/ha) in relation with availability of water (m<sup>3</sup>/ha) and comparing high-yielding varieties with the traditional ones, we can see that high-yielding varieties have greatly higher production. But on left side of graph we see that with lower water availability the traditional varieties are able to produce unlike the HYV which are not working in these conditions, and there exactly is the opportunity for alternative crops.

In most developing countries the climatic conditions are unstable, therefore is better to grow a broad variety of crops rather than a select few. The strategy of growing more genetically diverse crops is increasing the reliability of food production and facing-different seasonal variations more effectively. Also, NUS like African indigenous vegetables have some advantages such as shorter cycles, faster growth and a lower space requirement compared to local staple crops. Therefore, those minor crops are less vulnerable to environmental threats and risk of crop-failure is lower. Big benefit for agriculture is, that some of NUS like Seabuckthorn (*Hippophae salicifolia*) in the Himalayas, India, could even improve the quality of the soil itself. By its strong soil binding, water holding capacity and ability to fix atmospheric nitrogen in its root

nodules it may ameliorate degraded environmental conditions (see e.g. Dhyani et al. 2011; Jacobsen et al. 2015; Weller et al. 2015).

### **Nutritional values**

NUS may play key role in mitigating “hidden hunger” by way of a more diversified diet, leading to better micronutrient intake. NUS are already providing important nutrients for many tribal communities, NUS are rich of carbohydrates, fats, proteins, energy, vitamins-A, B1, B2, B3, B6, B9, B12, C, folic acid, and minerals-Ca, P, Fe, and dietary fiber. Their nutritional capacity can even prevent and cure various diseases like kwashiorkor, marasmus, night blindness, anemia, diabetes, cancer, hypertension, and hidden hunger. Some of NUS are also possess another desirable characteristics such as good flavours and, in some cases, also shorter cooking times (see e.g. Nandal & Brahvaj 2014; Bioversity International 2018).

### **Importance for tribal or “weaker” sections of societies**

In India in Rajasthan often the tribal or the “weaker” sections of society, including women and children, are collecting underutilized tropical fruits. Part of the fruit is used for their own consumption and part is sold on road side or to other local traders. This provides them with a sustainable source of income (Nandal & Brahvaj 2014).

### **Genetic resources**

NUS which include wild crop relatives are very important for gene bank databases. They are having important germplasm resource for improving future crop to achieve better characteristics like nutritional value and abiotic and biotic stress tolerances (Castañeda-Álvarez et al. 2016).

### 4.5.2. Weaknesses

NUS possess some weaknesses and marketing them is accompanied with many problems. The main points mentioned in literature speak mostly about insufficient knowledge (indigenous and scientific), undeveloped crop characteristics such as low yield, and many barriers before they reach the market.

#### **Low yield, laborious processing, short shelf life**

Underutilized crops are not widely bred to have good crop characteristics, therefore the yield of many underutilized crops is very low, though sometimes it may also be attributable to low inputs, cultivation, low plant densities or growing NUS on marginal lands. Those low yields are not wanted, and this is the reason why those crops are often replaced in favour of crops with higher yield. One of many examples of a traditional crop replaced by one with a higher yield, cultivated even 10 000 years ago is emmer (*Triticum dicoccon*) which almost disappeared in Italy and its production continues to decline in Turkey. All because emmer was pushed out by higher-yielding and more profitable crops like durum wheat (see e.g. Giuliani 2009; Jacobsen et al. 2015).

Another often mentioned problem is processing of NUS. Three important Andean grains, quinoa (*Chenopodium quinoa*), cañihua (*Chenopodium pallidicaule*) and amaranth (*Amaranthus caudatus*), have many benefits but what makes their cultivation complicated is that their growth cycles are long and processing their grain is a laborious and time-consuming task (Bioversity International 2018).

For many exotic fresh fruits the main problem for reaching global market is that they are having short shelf life and that they require careful storage and rapid transport to market (Hellin & Higman 2009).

### **Low awareness of customers, low awareness in scientific literature**

Consumers are often unaware even of the existence of these neglected plants, so they exclude them from their diets. This also lead to lack of demand, therefore farmers consider them less profitable and do not grow them. Because consumers and policy makers are not aware of all the benefits which NUS could offer and their consumption patterns are not well understood, only very little attention is given to their conservation, improvement, technologies, post-harvest handling and promotion or marketing. The cultivation and agricultural practices are poorly documented and the research how to breed them is inadequate, it therefore follows that there are not many improved varieties. Not only lack of interest, but limited funding, lack of clear research goals and journal apathy toward publishing work on NUS lead to very limited and often incoherent research. This may be main reason why we are still in this lock-in situation, when role players still continue in decision making with a conventional approach, despite it is not leading to their desirable outcomes any more. Nowadays agricultural lock-in situation continues in the case of the continuation of Green Revolution and its technologies, even though it probably cannot be able to ensure future food and nutrition targets (see e.g. Hughes 2009; Jacobsen et al. 2015; Mabhaudhi 2017; Bioversity International 2018).

### **Inappropriate classification**

Big problem for further research may be inadequate classification of NUS. For example in Turkey is decreasing production of emmer, but Turkish statistics do not make any difference between emmer and hulled wheat, both of them are reported as “spelt wheat” (Giuliani 2009). Thanks to this kind of problems we cannot clearly see how production of neglected emmer is decreasing or increasing.



### **Weak or any formal seed supply systems**

One of the main reasons why farmers are not cultivating some of neglected species is simple – they often do not even have access to appropriate germplasm of certain crop. Availability of the correct germplasm for farmers is the key precondition for growing certain crop. In some cases, even if farmers could buy the seeds in some market, knowledge how to manage and use this material is lacking (Janeckie et al. 2009).

### **Disappearing knowledge of farmers**

In some cases, the traditional knowledge about growing and utilization of NUS is enormous and well documented. In this case we can mention people in Uttarakhand and their know-how about seabuckthorn. But in other cases, the knowledge is slowly disappearing and there are not many efforts to document it. A serious problem for the future is that traditional knowledge is declining in younger generations, which are moving into urban areas. A study from India which was documenting folk knowledge on underutilized wild edible plants reported, that 60 % of people informing researchers about traditional know how were above 60 – 65 years. Not only knowledge about how to grow, but also how to prepare or cook some traditional underutilized crops is disappearing, sometimes it is already lost. Traditional knowledge about cooking millets in South India is already lost and recipes, cooking demonstrations and recipe books may help, but maybe it will not be enough to gain strong interest in product on the side of consumers (see e.g. Gruère 2008; Dhyani et al. 2011; Salvi & Katewa 2016).

### **Lack of policy frameworks, poor infrastructure and standards – a serious barrier for reaching markets**

Research in Nigeria collecting data from five villages and one hundred rural dwellers showed that the most accessible underutilized crops, in this case mushrooms, *Ocimum*

*gratissium*, and bush mango, are having significant contributions on household food security and generating income. But the marketing of these NUS faces many problems, mainly because there are poor efforts in commercializing them and policy frameworks of local market are lacking effectivity (Idowu 2009).

A study on emmer in Turkey pointed out that also poor infrastructure may be problem for reaching bigger market. Some of NUS are produced in marginal and remote lands, in mountains, in small villages and sold on local small market. To reach bigger market in a city may be a challenge when village is far away, and good quality of infrastructure is lacking (Giuliani 2009).

NUS produced by rural small-scale producers can be sold in markets which can be characterised in three major categories by the distance.

### 1. Domestic Market

This market is typical for low level of regulations which are mostly not formalised or enforced, sometimes either non-existent, therefore quality of product may be variable. It is adapted to local tastes and culture. Thanks to short distances from the farmer to the consumer the majority of products can be sold fresh. This market is good for selling NUS and achievable for a farmer.

### 2. Regional Market

This market distance is usually further and cross-border regulations may complicate easy flow of produce. Produce is usually sold fresh or processed and usually caters to traditional tastes. Often there are low-volume high-value produce sold, for example medicinal herbs. For small scale producers it is not so easy to be included in this value chain and increasing level of regulations it makes more difficult for producers of NUS.

### 3. International Market

Long transport routes for reaching this market require either processing of crops, low oxygen transportation or expensive air freight. Different tastes and strict regulations make it difficult for a new crop to be included in this type of market (Jaenicke & Lengkeek 2008).

In the case of the last point (3.), the international market is a big hurdle. Even if NUS are processed and considered attractive for customers, the required standards could be extremely hard to achieve. Public standards are needed for food safety and many of those requirements are not new. But as they become more strict, additional requirements bring new changes in cultivating (for example organic/Fairtrade production), which may necessitate high capital investments. Access to the market may require certification. For this is expensive third party needed and it can be a barrier for poor farmers (Hellin & Higman 2009).

A study “The impact of the European Novel Food Regulation on trade and food innovation based on traditional plant foods from developing countries” is the only study in our chosen literature focused on problematic of NUS reaching European market. The traditional crops are viewed as “exotic” and European Union’s Novel Food Regulation (NFR) is negatively affecting investments in supply chains and income generations in developing countries by making complicated for NUS to reach this market (Hermann 2009).

#### **4.5.3. Opportunities**

There are many opportunities for neglected crops to become more marketable. It is important to focus on the strengths mentioned above and try to deal with weaknesses.

For example, low yield and other crop characteristics are possible to improve by breeding. Better processing and conserving can make shelf life longer. By pointing out the benefits of NUS, the general awareness of them could increase in wider society. We can support growing them in marginal lands, they can be used to combat malnutrition, and also by higher contribution in agriculture NUS can improve production reliability.

Even though the rural communities are using underutilized crops for very long time, they are often called “new crops”. They are called new, because interest in them in researchers and companies appeared recently and are new for most customers (Padulosi et al. 2002).

Nowadays is a good time for NUS. In Europe, which is very attractive market, the interest in different food from developing countries is rising. Ageing and immigrant populations lead to higher demand for healthy and ethnic food. Also attributes of NUS like high content of vitamins, nutrients, unique flavour, visual attractivity, high amount of antioxidants, and absence of some allergens like gluten are contributing on higher demand (Hermann 2009).

### **Research, increasing awareness, promotion**

In sub-Saharan Africa is grown about 900 species of African Leafy Vegetables (ALV) by small-holders, in home gardens or gathered from the wild. ALV always was important part of diet of low income families and therefore was considered less prestigious, as food of the poor. It was not interesting for national agriculture and it was not considered easily marketable. Later through the work of collection, characterization, promotion and evaluation brought about the rescue of ALV. The dietary potential was determined, indigenous knowledge about their cultivation was documented and promising varieties were identified. Those steps increased demand and consumer acceptance, in farmers households volume and number of ALV species grown and the availability in local supermarkets increased. This is supported by study on a Biodiversity-led ALV project in Kenya which show that over 60 % of project participants reported that their income increased thanks to work with ALV. In addition

there was great increase in sales at supermarkets in Nairobi, where ALV sales increased by 1100 % in only 2 years (Bioversity International 2018).

There are many ways how to promote NUS. For example, in Slovenia promoting of NUS was done by marketing organic products from NUS on markets and by “Bio-party service” which was offering special food from forgotten crops on banquets, celebrations or other special events. Another case was project called „Healthy food and recreation for health strengthening and protecting” which was supposed to arise awareness among people in public institutions about nutritional benefits of organic food (Bravec 2009).

Another good example can be found in India and minor millets. These small-seeded crops, rich in B vitamins, calcium, iron, potassium, magnesium and zinc, are still making less than one percent of the food grains worldwide. Processing takes a long time and hard labour, but on positive side this crop needs only little water and can survive in conditions where other crops would fail. Improving planting techniques of millet, focusing on traditional knowledge and selection of higher quality varieties brought positive results. The yields of Indian small millet growers increased by 70 % and income of those farmers was increased by 30 %. Women farmers were included in the process– they were trained for selecting and packing grain into snack foods. This product is more marketable, so it is sold to urban markets and schools. Indirect public support of NUS like including meals from traditional crops in school meal programmes, military rations or providing meals from NUS in hospitals may help. Policy support like information campaigns, collective purchases or consumption subsidies could also increase production of NUS (see e.g. Gruère 2008; Bioversity International 2018).

### **Processing, value addition, and attractive high-end products**

There is big potential for underutilized fruit. Addition of value is including processing of raw material, creating edible and more usable forms and making them easier to transform. These products mostly possess higher storability and shelf life. This value addition is also increasing socioeconomic status of rural families and it is generating

employment for more people. About value chain we can find also more information in study “Marolo (*Annona crassiflora* Mart.): a study of value chain and processing”. This study is focused on marolo fruit in Brazil, where is this fruit mostly processed to make ice cream, candy, jelly, and liquor (see e.g. Corrêa 2013; Nandal & Brahvaj 2014).

As was mentioned above, we can see that interest in exotic, fair trade and organic foods is growing in attractive big markets, like the European one. Thanks to accessible transport and efficient marketing the exotic foods are available and quite cheap. Even though globalization may be in many cases problem for producers such as small-scale farmers, it also can bring new opportunities. Growing demand for products from NUS is creating global value chains which can be new source of income for rural small holders growing NUS. Successful examples may be acerola (*Malpighia emarginata*) or camu-camu (*Myrciaria dubia*), both rich for vitamin C, or naranjilla, also called lulo (*Solanum quitoense*). Other crops which made it to global market are yam bean or jicama (*Pachyrhizus erosus*) from Mexico or Andean crop quinoa (Jacobsen et al. 2015).

Also some neglected crops may interest big companies, because they can be used as material for processed food. For example emmer could be used for new kinds of pasta or flour, which is making new opportunities for absolutely new products (Giuliani 2009).

### **Increasing food security and mitigating hidden hunger**

In some developing countries it is not easy to provide safe and nutritious food. In the Philippines is increasing price of imported food, and sometimes even a product as simple as flour may be too expensive for the local population. Therefore, people in Philippines began making own flour from local root tubers to provide better food security. Good root tubers for making flour are gabi (*Colocasia esculenta*), galiang or wild gabi (*Xanthosoma saggitifolia*), ube or yam (*Dioscorea alata*), and camote (*Ipomoea batatas*). But to achieve this, it was needed to gain technical knowledge about

producing flour, which was lacking there, especially in regard to underutilized tubers (Balangcod & Vallejo 2013).

Many people may not suffer by hunger, but they may be malnourished. Three major nutrient deficiencies causing illnesses and deaths are because lack of iron, vitamin A and iodine. Higher diversity in agriculture helps to increase food diversity which is having key role to improve micronutrient deficiencies and mitigating hidden hunger (Hughes 2009).

### **Collective action**

For small scale farmers producing NUS may be problem when trading with supermarkets. Supermarkets prefer large, stable and reliable supply of goods, and this is big challenge for small-scale farmer. Collaboration of small farmers and uniting into larger collectives can provide more stable production and facilitate a far-reaching market. Together it is easier to achieve their objectives. A study focused on collective action in the marketing of NUS in India shows, that collective action initiatives are having very important role in market development of NUS. Minor millet in Kolli Hills was facing weak demand by customers. It was caused by lack of information about millets in society. But groups of farmers were able to develop a market for this underutilized crop and it may to lead to higher consumer acceptability (Gruère 2008).

### **Agrotourism**

There is big potential for additional income from growing NUS. An example comes to us from Italy, where emmer (*Triticum dicoccon*), cultivated for centuries almost disappeared because of more productive durum wheat. To rediscover emmer and increase its production again helped increasing interest in its nutritional values and local traditions, but also tourists, visiting emmer regions. Visitors were interested in history, folklore, nutritional content and they were trying emmer soups and other products (Guiliani 2009).

## **Payment for Ecosystems Services (PES)**

For many farmers may be main reason to not grow NUS because some of them may not be so profitable. Farmers need some motivation in form of money. Maybe a good solution can be Payment for Ecosystem Services. This mean that land users will be paid for ecosystem services which are benefits wider society. As the ecosystem service may be considered sustainable and diverse farming and using NUS in their agriculture (Narloch et al. 2011).

### **4.5.4. Threats**

With higher production of NUS and including them into market chains may appear many problems like overexploitation of fragile lands or higher prices of traditional products for local people. It can happen when food crop become to be grown as a cash crop. Also when we are thinking about marketing of certain crop, we need to think about problems which we may have, like food taboos. We need to be sure, that if we will introduce new product, that it will be accepted by customers.

#### **Increasing production, increasing prices**

In the case of quinoa, we see what can happen if a NUS succeeds on the global market. In figure 6 we can see how dramatically production of quinoa increased over the last few years. This huge increase of production also leads to negative consequence like lower agricultural diversity, because quinoa replaced most of crops.



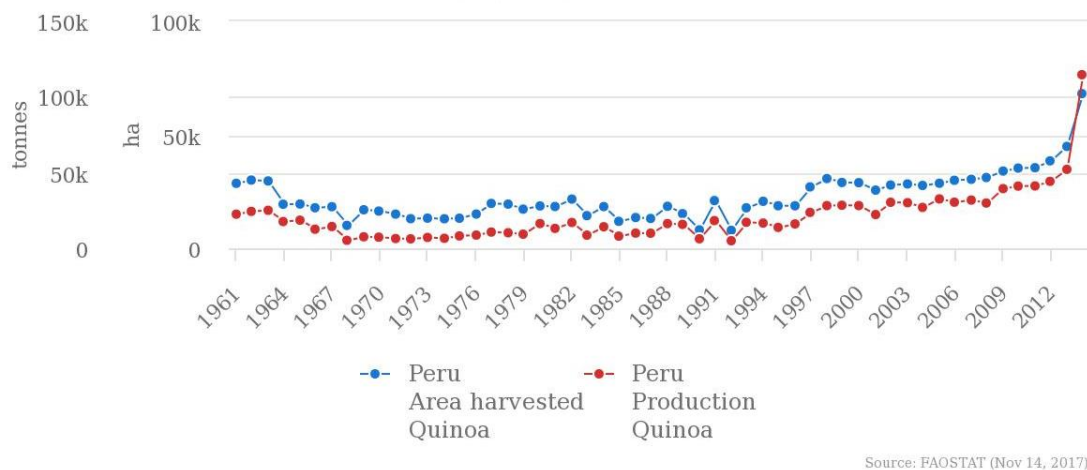


Fig. 6. Annual production/yield quantities of quinoa in Peru from 1961 to 2014. Source: (FAOSTAT 2017)

A second problem arises when the huge increase in production is accompanied by huge increase of prices as we can see in figure 7. This high price is also for local people, so for farmers is better to sold crop instead of using it as a food.

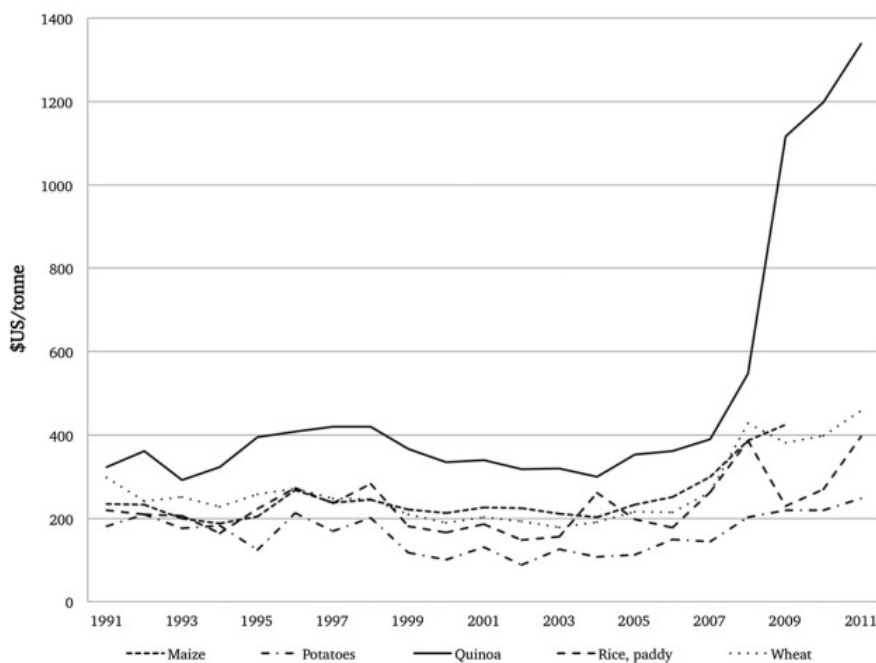


Figure 7 Annual prices for staple crops and quinoa in Peru.

Source: Stevens 2017

So we can conclude that higher production of quinoa in Peru is changing eating patterns of local people, which are not eating their local nutritious crop anymore, because it is not affordable for them as consumers. But also we need to mention that this trend is supported by growing urbanization. With growing urbanization many consumers are changing also their food preferences from traditional diets to energy-rich, simple food, which is sometimes lacking nutrients, but this is fast and cheap (Jacobsen et al. 2015).

### **Loss of biodiversity within the taxon**

Higher integration of NUS into agriculture is increasing biodiversity and it brings many benefits. But significant expansion in cultivation of a particular underutilized plant may have negative consequences for this underutilized plant itself. There is high possibility that genetic variation within the taxon will decrease. A study about the native chilli varieties in Peru shows, that the farmers selling the crop to wholesalers (which are preferring more uniform crop products), are growing a smaller number of varieties than farmers selling the crop to retailers. So market participation is having counter-effect of favouring the cultivation of uniform commercial crop varieties, which is contributing on erosion of crop genetic diversity. Another example we can see again in production of quinoa. It is desired by market to have large-grained variety and white colour is in favour of customers, therefore the White Royal quinoa become the most frequently exported and cultivated variety at the expense of other quinoa varieties (see e.g. Janeckie et al. 2009; Garcia-Yi 2014; Yusuf 2015).

### **Social acceptance and low status of some NUS**

A serious threat in the introduction of a new crop to the market may come in the form of social unacceptance. A study from India focused on underutilized tropical fruit and security of local tribes is addressing various deficiency diseases, malnutrition and health

insecurity to local eating habits, taboos in food and cultural myths. Social acceptance is one of main factor which is needed to consider when we would introduce new product on market. We also need to consider that many of traditional food crops are linked to rural, small-scale farmers. Urban consumers may not be interested in NUS that much and traditional plants are considered as something less prestigious (see e.g. Nandal & Brahvaj 2014; Jacobsen et al. 2015).

### **Unsustainable harvesting methods**

Many NUS, especially those with medicinal properties are threatened by unsustainable harvesting methods (Hoeschle-Zeledon 2007). Sometimes it may be because farmer wants fast income, but sometimes because lack of knowledge how to treat plant to achieve long term sustainable production.

## 5. Conclusions

Total number of 307 results which were focused on topic of neglected and underutilized crops were identified at the Web of Science. Found scientific literature was analysed, the most cited results were mentioned, also journals and publishers which published most of our results were discussed. Graphs about results per year since 2000 and classification of articles were made. Most common was Agriculture, Plant Sciences and Food Science. In second part was chosen scientific literature about NUS related to economical topics. Those results were examined and main points which were mentioned were selected, separated and SWOT analysis was made out of them. SWOT analysis shows, that NUS are having strong points like climate change resilience, high nutritional values and are important for local communities. The problem is that they do not have the same positive characteristics such as high yields etc. Farmers are also having problems with missing seed supply, processing and short shelf life of NUS. Reaching market is not easy due standards, traditional knowledge of local people is disappearing and awareness of NUS in society is lacking. But anyway, NUS are having big economic potential. Good knowledge about nutritional attributes of NUS is useful for promotion, decision support for producers and for motivation to buy it by consumers. Many of NUS contain antioxidants (amaranths, sweet potato, etc.) some are rich in amino acid compositions (amaranths, quinoa, buckwheat, underutilized legumes), some of them are rich in fiber and minerals, many of them are gluten free (buckwheat, grain amaranth, quinoa, millets), making these good products for people with celiac sickness. Value addition is making NUS more marketable and it is generating new jobs. Farmers may supply stable production by making bigger groups and agrotourism or payment for ecosystem services may also increase production of traditional crops. Also problems which may occur were mentioned. The negative effects of food crop becoming cash crop was mentioned same as threat for marketing new crop like social unacceptance.

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