**FOOD SCIENCE & TECHNOLOGY | REVIEW ARTICLE**

*Moringa oleifera*: A miracle multipurpose tree for agroforestry and climate change mitigation from the Himalayas – A review

Sabina Devkota* and Khuma Kumari Bhusal

**Abstract:** Drumstick (*Moringa oleifera* L.) is native to tropical and sub-tropical regions of South Asia. It is also growing in Nepal; however, underutilized crop species. The excellent benefits of moringa offer global cultivation in recent years; however, it is still categorized under-utilized species in Nepal. Recently, efforts are being carried out by researchers, policymakers and nutritionists on its prospects for future-smart food in Nepal. *Moringa oleifera* is a highly nutritious food crop along with promising characters like rapid growing and drought resistance. We reviewed the prospect of *Moringa oleifera* as an agroforestry tree in Nepal. Here we briefly discussed its distributions, cultivation and production status in Nepal, and its multipurpose uses. Data and information were collected from newspapers, journals and the Ministry of Agriculture and Livestock Development.

**ABOUT THE AUTHOR**

We are an undergraduate student at Tribhuvan University. During our bachelor course, we need to write a review paper for one course. We collected the information from different national and international journals, websites, personal blogs and daily newspapers. We presented the collected information from the perspective of food security and agroforestry. The reason is that Nepal has poor performance in food security and the possible area of moringa cultivation (terai plain area) is suffering more. Hence, by employing moringa based agroforestry those people under acute vulnerability could benefit from the double advantages of Moringa cultivations.

Mrs Sabina Devkota Gokuleshwor Agriculture and Animal Sciences, Department: Plant Sciences, Position: Student. Email: devkotasabina32@gmail.com, Cell: +977-9846439913, Address: PO Box 10212, A.P.O, Gokuleshwor, Baitadi, Nepal

**PUBLIC INTEREST STATEMENT**

This paper has reviewed the potential of Moringa based agroforestry cultivation in Nepal. We searched the studies related to its food and nutritional values, agroforestry and production sites and status in Nepal. We examine the possibility of expansion of land under Moringa cultivation in Nepal based on existing government policies and its multifaced uses. We presented the views from future-smart food (FSF) and agroforestry perspective. Further, we addressed the idea for commercialization of Moringa in Terai and mid-hills regions of Nepal unbundling from neglected and underutilized species. The result of this work could be a roadmap for the researcher and policymakers of the country because we have analyzed the possible interventions in Moringa cultivation in Nepal. The result indicated that Moringa is the superfood and could be utilized for overcoming the food insecurity of the country. However, the legislative support to farmers and possible innovation of technologies for moringa-based agroforestry is needed.
Available literature suggested that it is considered as an “ideal tree” for agroforestry. A review of the literature indicates that *Moringa oleifera* under the multistoried cropping pattern under the shade of this tree is highly effective for crops. The tree is less sensitive for price change, hence, it can overrides monocropping. Also, the agroforestry with *Moringa olferia* plays a vital role in soil and water conservation. Further, we recommended a research study on the most suitable crops under agroforestry with this tree, the economic analysis of the moringa-based agroforestry system and the effect of shade due to moringa tree on soil quality.

**Subjects:** Agriculture; Agricultural Development; Agriculture and Food

**Keywords:** under-utilized species; medicinal and nutritional value; miracle-tree; agroforestry; climate change

1. **Introduction**

*Moringa oleifera* L. is a non-flowering tree plant commonly known as the ‘Drumstick’ or horseradish tree. It belongs to the genus *Moringa* (Box 1), which has 13 different species. It is a small deciduous tree usually 5–10 m tall but sometimes up to 15 m, with a light, feathery canopy. It is native to India. Nevertheless, Nigeria, the Pacific Islands, the Caribbean, the Philippines, South Africa, Asia, Florida and Latin America are widely grown (Fahey, 2019). It has diversity in its name such as “Shiferaw” in Ethiopia and drumstick tree or horseradish tree in India and “Sitlachini,” Munga, Sahijian or Sajian in Nepal. It is a fast-growing, multi-purpose tree. A study showed that *Moringa* is highly drought-tolerant (Nepal FAO, 2018) and one of the most useful trees due to its medicinal and nutritional properties in the world. Hence, globally described as a “miracle tree” (Yishehak et al., 2011). It is reputedly known as “cabbage tree”, “drumstick tree” or “horseradish tree”, “benzoil tree”, “miracle tree” and “mother’s best friend tree” (Koul & Chaw, 2015). It has multipurpose use, well adapted and significant economic importance, as it has vital nutritional, industrial, and medicinal applications (Dawit et al., 2016; Sreelatha & Padma, 2009). It’s all parts (leaves, fruits, immature pods, and flowers) are combined into the traditional food for human consumption (Dhakad et al., 2019).

The tree grows well in climate ranging from warm tropical at sea level to sub-tropical up to an altitude of 3,000 ft (Li & Siddique, 2018). The maximum temperature for growth and development of the tree ranges from 38 to 48°C and at least −1 to 3°C. Quite sandy soil in texture favors *Moringa* cultivation, though it grows in most other than stiffy clay of shallow hills (Omonhinmin et al., 2020). A study showed that the Moringa tree was found as a wild and cultivated form throughout the plains, especially in hedger and in-house yards, thrives best under the tropical climate and is abundantly near the sandy beds of rivers and streams (Olson, 2019). In two different ecological locations, semi-deciduous and Savannah regions, the nutritional component in leaves seems to be diverse (Asante et al., 2014). Interestingly, it can grow well in the soil with slightly acidic to alkaline pH and an annual rainfall of 250–3000 mm (Kumar et al., 2019).

*Moringa* tree has multiple uses and functions. It is used as alley cropping (bio-mass production), animal forage (leaves and treated seed cake), biogas (leaves), a cleaning agent (crushed leaves), blue dye (wood), fencing (living trees), fertilizer (seed-cakes), foliar nutrient (leave juice), green manure (leaves), gum (tree trunk), honey and juice clarifier (powdered seed), honey (flower nectar), medicine (all plant parts), ornamental planting, bio-pesticide, rope (bark), tannin (bark and gum) (Mansour et al., 2020). Besides, the *Moringa* tree has significant economic importance, as it has a considerable role in a nutritional, industrial and medicinal application (Dawit et al., 2016). The study in different countries reported that almost all parts of the tree are used for human consumption. In Africa, it is used as food (Ozcan, 2020). Moreover, the Moringa tree plays an essential role in mitigating climate change and increasing the incomes of small-holders. In Nepal, Moringa is a neglected and underutilized species, often
used in agroforestry. Interestingly, *Moringa*’s agroforestry offers economic benefits to small-holders and local communities while helping to create resilient landscapes. A study reported that *Moringa*-growing agroforestry systems in association with other crops were more profitable than a monocropping system (Shode & Amanuel, 2016). However, the consumer and farmers are not aware of its multifaceted uses. We reviewed the potential of moringa tree from the prospectives of agroforestry. The distribution and production in Nepal, its food value, prospects to climate change and agroforestry are briefly discussed in this paper. The study aimed to summarize the literature available on moringa-based agroforestry and briefly discussed for better understanding of the prospective species as potential future-smart food for Nepal.

2. Origin and geographical distribution of *Moringa oleifera* L. tree
*M. oleifera* L. is indigenous to northern foothills of India, Pakistan and Nepal (Leone et al., 2015). Much genetic diversity is mainly available in the Terai region of Nepal and Uttar Pradesh of India (Ray et al., 2020). Moringa tree has much more diversity in species, which includes thirteen known species in the genus *Moringa* of family Moringaceae. These are *Moringa oleifera*, *M. arborea*, *M. borziana*, *M. con-canensis*, *M. drouhardii*, *M. hildebrandtii*, *M. longituba*, *M. ovalifolia*, *M. peregrine*, *M. pygmaea*, *M. rivae*, *M. ruspoliana* and *M. stenopetala*. *Moringa arborea*, *M. borziana*, *M. longituba*, *M. pygmaea*, *M. rivae* and *M. ruspoliana* are native to some regions of Africa, and exist nowhere else in the world. Similarly, *M. drouhardii* and *M. hildebrandtii* are native to Madagascar. These two, along with *M. ovalifolia* and *M. stenopetala*, both native to parts of Africa, are called “bottle trees.” The stalked glands can distinguish *M. oleifera* L. at the leaf base and rachis articulations; the three-valved fruits; the three-winged seeds and by a pungent horseradish odor from the leaves (FNAEC, 2017). *M. oleifera* is found worldwide in the tropics and subtropics. The species is present in Asia, Africa, North America, Central America, the Caribbean, South America and Oceania.

3. Cultivation and production
*Moringa oleifera* cultivation in Nepal is in a ‘rudimentary stage of evolution. Cultivation of this “tree for life” seems zero. In recent years, a handful of entrepreneurs, however, got involved in its plantation. Some farmers of the Terai regions have started the cultivation of moringa since 2009; however, its commercialization in Nepal is still in infancy.

The mid-hills and foot-hills region of Nepal is the most suited climate for *Moringa* tree cultivation. However, some areas of the Terai are also providing a relatively adequate environment for its cultivation. Interestingly, Uprety et al. (2012), on his feasibility study of *Moringa* tree cultivation in Nepal, suggested that Terai, Siwalik and Middle Mountain regions are the best-suited regions due to the elevation factor and climatic conditions. The Bajura district of Far west province is the leading district of *Moringa* production among the thirteen districts of Nepal. Much genetic diversity is mainly available in the Terai region of Nepal and India (Uttar Pradesh) (Sthapit et al., 2008). Thus, *M. oleifera* has found wide acceptance, recognition and usefulness among the various ethnicities in different parts of Nepal. In Nepal, *M. oleifera* L. is produced in the land area of 67 ha and 554 metric tons per year (FAO, 2018). Still, *Moringa* is underutilized and neglected species (NUS) of Nepal and mostly consumed by Terai people in Nepal (Sthapit et al., 2008). Interestingly, Pacific of the FAO (2018) qualified six NUS, and one of them is Drumstick tree as future-smart food for Nepal, to reinforce the importance of agricultural diversification.

3.1. Potentiality of *Moringa* cultivation in Nepal
*Moringa* is widely adapted to the tropics and subtropics. It grows well in a temperature range of 25°C to 35°C, but it also tolerates light frosts and temperatures up to 48° C (Pokhrel et al., 2016). *Moringa* is a drought-tolerant tree that can grow well in poor soil conditions or marginal lands with minimal rainfall. The tree grows well in areas receiving annual rainfall amounts that range from 250 to 1500 mm. Altitudes below 600 m. are best for moringa, but this adaptable tree can grow in altitudes up to 2000 m. in the mid-hills regions of Nepal. Moringa prefers a well-drained sandy loam or loamy soils. It does not tolerate prolonged flooding or poorly drained clay soils. It will tolerate a soil pH of 5.0–9.0. The Terai and Siwalik regions of Nepal are mostly situated at 300 to 1400 masl with a temperature of 35 to 43° C during summer, having marginal land with fragility...
and poor nutrient conditions. Therefore, these regions could be the best location for the growing Moringa tree. Moreover, a growing moringa tree can be a good option for reclaiming the marginal land of the Siwalik region of the country.

3.2. Policies support for NUS in Nepal

The government of Nepal with collaboration with the Food and Agriculture Organization (FAO), six neglected and underutilized species (NUS) are qualified as future-smart foods and one of which is Moringa (Table 1). The NUS qualification was based on their cultural and nutritional values, food, nutrition, health and climate change importance. The government of Nepal has taken initiatives to encourage NUS production in lower food production areas in the country’s 14th three-year national plan. Then, the Ministry of Land Management, Agriculture & Cooperative (MoLMAC) announced the 58-points agricultural transformation roadmap in 2018 which emphasized the promotion and conservation of NUS. From fiscal year 2018/19, the promotion of NUS was started in three districts, namely Lamjung, Humla and Bajura representing three provinces Gandaki, Kamali, and Far-western respectively. Later this program was extended to 12 districts of Nepal. Then, each policy and annual program are addressing the promotion and commercialization of NUS.

4. Food and nutrition insecurity in Nepal

The population of people experiencing acute food and nutritional vulnerability is 0.50 million. About 54 percent of the country’s total population faces chronic food insecurity (Table 2). Low scale of production, poor roads and their connectivity and other services, cause most people living in the mountainous region, frequently suffering from food deficits (National Planning Commission (NPC), 2017). Resource-poor households residing in food surplus areas in Terai districts are suffering from malnutrition and lack of entitlement, primarily due to dysfunctional governance and policies (National Planning Commission (NPC), 2017). More than 18.7 percent of the population remains under the absolute poverty line and the multi-dimensional poverty index is 28.6 percent (Ministry of Finance, Nepal, 2020). This is a major challenge for the country to meet the Sustainable Development Goals (SDGs).

4.1. Food and nutritional value of Moringa

Moringa is famous as an excellent source of nutrition and a natural energy booster. It has been promoted by the WHO as an alternative food source to treat malnutrition (Sreelatha et al., 2009). Moringa contains many more nutrients and minerals (Table 3). Moringa leaves contain more vitamin A than carrots, more Vitamin C than an orange, more potassium than bananas, and on top of that, the protein quality of Moringa leaves competes with that of milk and eggs (Fahey, 2019). Each part of the Moringa tree (fruits, seeds, leaves, flowers, bark and roots) is associated with the presence of at least one, or in the greatest number of benefits (Zaku et al. 2015). The analysis of dietary iron supplements in the liver influenced by M. oleifera leaves revealed that iron from Moringa can overcome iron deficiency (Saini, 2014). Thus, Moringa can play an essential role in food and nutrition security of the people in Nepal, which will have implications for achieving the SDGs goals one and two as well.

| Table 1. Qualified neglected and under-utilized species in Nepal |
|---------------------------------------------------------------|
| **Food crops** | **English name** | **Scientific name** |
| Cereals          | Tartery Buckwheat | *Fagopyrum tataricum* (L.) Gaertn |
| Roots and Tubers | Tara              | *Colocasia esculenta*          |
| Nuts and Pulses  | Grass pea         | *Vicia sativa*                 |
| Horticulture     | Drumstick         | *Moringa oleifera*             |
|                  | Jackfruit         | *Artocarpus heterophyllus* Lam |
|                  | Nepal Butter Tree | *Bassia latifolia* Roxb        |

Source: (FAO, 2018)
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| Table 2. The demographic, social, economic and financial status of Nepal |
|---------------------------------------------------------------|
| Province | Multi-dimensional poverty (%) | Poverty rate (%) | Poverty vulnerability (%) | Poverty intensity (%) | No. People under poverty (Millions) |
|----------|-------------------------------|------------------|---------------------------|----------------------|-----------------------------------|
| Province 1 | 19.7                          | 16               | 3.6                       | 1.1                  | 0.72                              |
| Province 2 | 47.9                          | 27.7             | 7.1                       | 2.4                  | 1.48                              |
| Bagmati   | 12.2                          | 15.3             | 4.8                       | 1.6                  | 0.83                              |
| Gandaki   | 14.2                          | 15.3             | 4.2                       | 1.4                  | 0.41                              |
| Province 5 | 29.9                          | 25.8             | 6.5                       | 2.3                  | 1.05                              |
| Karnali   | 51.2                          | 36.5             | 10.1                      | 3.7                  | 0.59                              |
| Far west  | 33.6                          | 42               | 12.1                      | 4.6                  | 1.06                              |
| Average   | 28.6                          | 25.2             | 5.43                      | 1.81                 | 6.15                              |
| Source: Nepal Rastra Bank, Nepal, 2020 |

| Table 3. Comparison of Moringa fresh and dry leaves with common foods per 100 grams |
|-----------------------------------------------|
| Nutrient | Common foods | Moringa leaves |
|----------|---------------|----------------|
|          | Fresh leaves  | Dried leaves   |
| Vitamin A | 1.8 mg Carrots | 6.8 mg         | 18.9 mg         |
| Calcium  | 120 mg Milk   | 440 mg         | 2003 mg         |
| Potassium| 88 mg Banana  | 259 mg         | 1324 mg         |
| Protein  | 3.1 g Yogurt  | 6.7 mg         | 27.1 g          |
| Vitamin C| 30 mg Orange  | 220 mg         | 17.3 mg         |
| Source: (Chukwuebuka, 2015) |

5. Prospects to climate change

Nepal is one of the least developed countries in the world and ranked as the 4th most vulnerable country in terms of climate change impacts; however, Nepal has the least contributor to global GHGs emissions, emitting 0.027% of the global total. Therefore, Nepal and its people are under acute vulnerability in terms of climate change.

Impacts of climate change need to be realized from household livelihoods to national food security for the adaptation process. Livelihood has a direct connection with climate change on all the assets (human, social, natural, physical and financial capital). Adaptation includes activities like reducing poverty, improving access to resources, lowering inequities of resources and wealth, improving education, improving infrastructure, improving institutional capacity and efficiency and promoting local indigenous knowledge (Thakur & Bajagain, 2019). As such, Moringa can be pivotal in solving both issues: related to climate change and livelihood. The Moringa tree can absorb 50-times higher compared to the Japanese cedar tree and also twenty times (20x) higher than that of general vegetation (Villafuerte & Villafurte-Abonal, 2009). Thus, the carbon sinking attribute of Moringa can be utilized to curb the effect of global warming and in the meantime the problem of malnutrition, hunger, poverty, and unemployment of the country.

6. Prospects of Moringa tree for agroforestry use

Land used under agroforestry provides more benefits than a monocropping land-use system. A study on the benefit-cost ratio of the fruit tree-based agroforestry system reported a higher return than that monocropping (Rahman et al., 2017). Neupane and Thapa (2001) studied the financial analysis of agroforestry over mono-cropping in the central region of Nepal. The study reported that the net benefit of agroforestry cultivation is about 44 to 58% superior to non-fertilized continuous maize production.
practice (Kassa, 2015). Under the study of the evaluation of the agroforestry system under different marketing and institutional environments, the result showed that the profitability of agroforestry is almost four times higher and is attractive than any other land-use systems (Paul et al., 2017).

Moringa can be quickly established by cutting or by seed. Plants grown from 1 m cuttings beat pods form the second year of growth onwards, with maximum production at 4 to 5 years. In a favorable environment, a single tree yields 50 to 70 kg pods in a year (Zheng et al., 2016). The practice of intercropping has been shown to the result that it makes efficient use of natural resources (Zohry & Ouda, 2017). Throughout the lifetime, it can be integrated with various shade-loving crop plants and hence farmers can take benefit from the adoption of agroforestry. Moringa also can be planted in alley cropping. It has been proved that Moringa alley cropping decreases soil acidity (Abdullahi & Anyaegbu, 2017). Multiple uses of the tree facilitate its production and can be suggested to local farmers for agroforestry.

7. Conclusion and recommendation

Moringa oleifera L. is a plant native to India, but it is widely grown globally. Unfortunately, it is under-exploited and underutilized in Nepal. M. oleifera is cultivated in the eastern hilly areas, mostly in Dhankuta, Dharan, Ilam and Panchthar districts and in the Terai regions of Nepal (Thapa et al., 2019). The cultivation is limited only to mid hills and few terai regions of Nepal whereas consumption is limited to a certain community only. The multi-use of this tree is yet to be exploited. India utilizes the medicinal benefits of different plant parts, but in the case of Nepal, only the pods are used as vegetables. Fresh Moringa leaves can be used in vegetables. Leaf powder can also be consumed as food, nutrient supplement and medicinal purpose. The tender pods can be consumed as boiled, steamed, and fried and the seeds can also be consumed like peas. Moringa can be effective in assuring food security by breaking the monoculture and also promote the promotion of other neglected and underutilized crop species. However, a research study on the nutrient composition of the Moringa tree in Nepal is necessary. Nepal government has classified the moringa tree as a future-smart food because of its higher nutritive value lower cultivation cost. Hence, it has a high potential to eradicate food insecurity problems in tribal communities such as Chepang, Musahar, and other indigenous communities. Besides, it can be successfully planted in agroforestry. The farmers can be highly benefitted by cultivating the tree in marginal lands such as Chure, including less-irrigated land and riverbank of Mid-hills. The cultivation of under-exploited trees has a considerable possibility to uplift the economic status of local farmers. However, a research study on the combinations of crops for agroforestry with moringa that gives optimum yield and return its outmost. Hence, the farmers should be encouraged for the expansion of the cultivated area of moringa by adding the value and establishment of proper supply channels in the country.

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Author details
Sabina Devkota1
E-mail: devkatssabina12@gmail.com
Khuma Kumari Bhusal1
1 Department of Horticulture, Gokuleshwar Agriculture and Animal Science College, Gokuleshwar, Baitadi, Nepal.

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