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"What Will We Eat?"—Creating A Sustainable Food Supply for the Virginia Highlands and Other Temperate Mountainous Regions Using Agroforestry

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Abstract

Detailed plans are presented for introducing agroforestry as a primary food source for Climate Change Haven Communities in the Virginia Highlands Region of the Appalachian Mountains. Primary emphasis is placed upon using fruits, grains, vegetables, nuts, and legumes as food sources. These plans may be transferrable to other mountainous areas of the Earth having temperate, subtropical climates.

Keywords

Sustainable Food Supply, Agroforestry, Appalachia, Virginia Highlands, Climate Change Haven Communities

1. Introduction

As our planet enters the second half of the 2020-2030 decade, it is apparent that little to no progress has been made in attempts to ameliorate climate change. Carbon dioxide levels are currently at their highest levels in human history, rising sea levels are flooding coastal communities, Arctic air is now intruding across the upper levels of the Northern Hemisphere with increasing frequency, and wildfires and droughts have become endemic across much of the American Southwest, Africa and Northern Asia [1]-[6].

As a result, human migration from severely affected regions of the planet has intensified over the past few years and is now be considered one of the most pressing issues confronting nations globally [7]-[10].

Within the United States, Federal-level climate change monitoring and remediation programs have been eliminated or greatly reduced in budgetary funding over the past year; the most recent example being the elimination of Federal funding for current off -shore wind turbine projects [11]-[13].

Therefore, Federal funding will not be available for the project proposed in the present study. In lieu of Federal funding, the project, which presents an agroforestry food program for climate-threatened Americans migrating to safer areas of the United States, will require funding by commercial real estate development companies having the necessary financial resources [14].

The primary goal is to show that an agroforestry food supply project is environmentally feasible in the Virginia Highlands Region of the Appalachian Mountain Region. The study proposes that because the Appalachian Mountain Region has a predominately temperate, subtropical climate, is substantially forested, and has medium to tall mountains, it possesses the characteristics necessary to create a successful agroforestry food supply program. It is probable that the sustainable food supply system described here can be used in other regions of the world having similar terrain and climate. In these other global regions, e.g., the European Union and China, central governments are likely to be willing to provide the funding for the implementation of this food supply system, and their citizens will not have to rely solely on private, corporate financing.

2. Agroforestry

"Agroforestry" is the intentional integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits. It has been practiced in the United States and around the world for centuries. Within the United States, agroforestry was being used by Native Americans (see **Figure 1** below) prior to the arrival of European colonists in the 1500s and 1600s [15]. These techniques were adopted and adapted by the arriving colonists in Virginia and Massachusetts during the 1600 to 1700 time period [15] [16].

Figure 1. Indigenous agriculture in the Appalachian Mountains.

However, in the United States and much of Europe, modern agriculture is now based on monocropping/industrial agriculture. This is a farming system in which

large areas of land are cleared of indigenous vegetation and planted with high-profit crops, for example, soybeans, corn, wheat, and lettuce as shown in **Figure 2** below). These crops are produced using copious amounts of chemical fertilizers, herbicides and pesticides [17] [18].

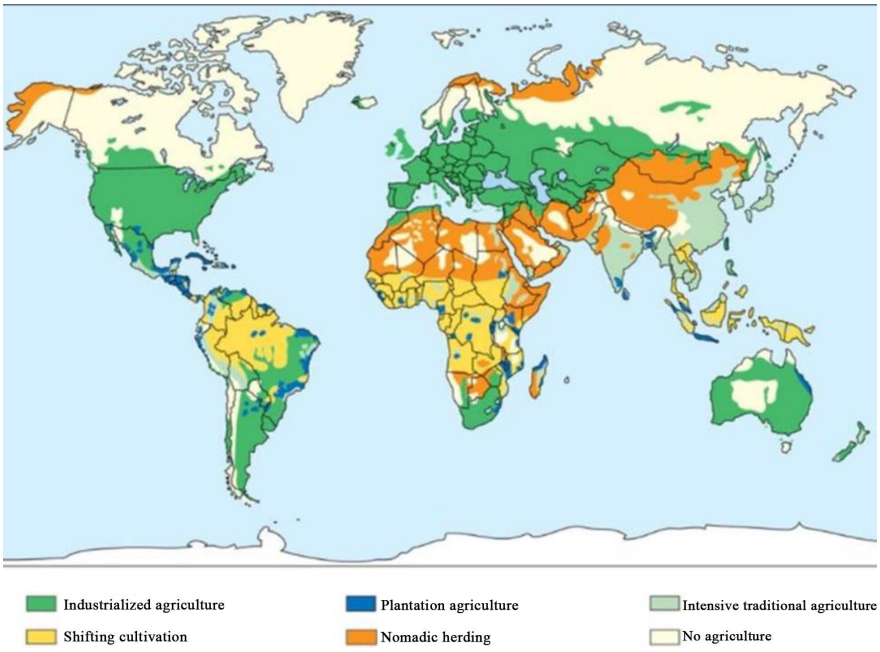

Figure 2. Industrial, monocropping agriculture is globally widespread.

In doing so, they gain widespread geographic dispersal, contributing to climate change [19]. **Figure 2** shows a global map of the current use of monocropping, (*i.e.*, industrial agriculture). As can be seen, virtually all of the United States, much of South America, Australia and the European Union are dependent upon this form of plant cultivation. **Figure 3** below shows a typical industrial agriculture crop; note the machine spreading chemicals.

The present study describes the use of three types of Agroforestry. These do not contribute to climate change and, in fact, will help reduce the negative impact of current climate change. This plan is applied to the 39 mountainous counties of Virginia, termed the Virginia Highlands. The agricultural model presented is applicable through-out the Appalachian Region and should also be utilizable in mountainous regions of the Northern Hemisphere having temperate, subtropical climates, together with adequate forest and woodland cover. The tree cover is necessary to protect the planted areas from excess rainfall, drought and wind [20].

Figure 4 below depicts areas of the planet in which temperate, subtropical agroforestry will be possible. As climate warming continues, boreal forest zones may also become viable for agroforestry food production. However, utilization of these northern zones may be impeded by the increasing frequency of Arctic air intrusions which may damage or destroy efforts to introduce temperate zone plants

and animal species in far northern regions [21].

Figure 3. Monocropping in the United States. Note the machinery spreading insecticides and fertilizers across the rows of vegetables.

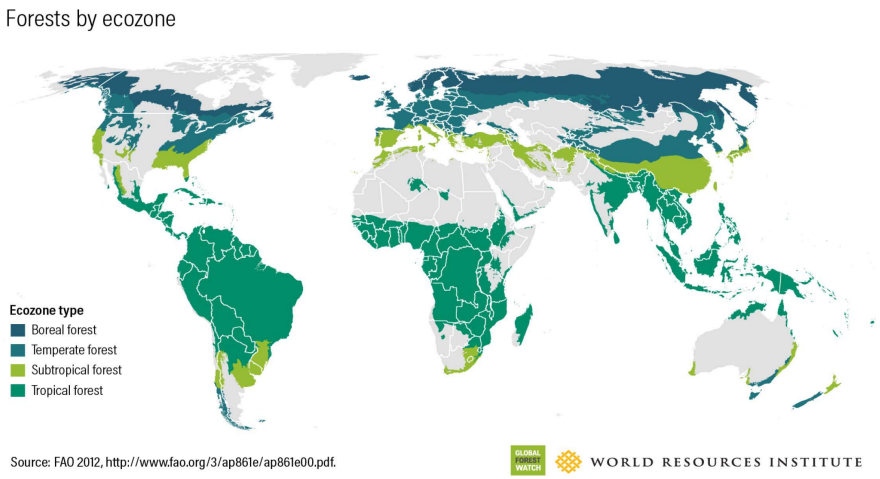

Figure 4. Current forest types by Ecozone.

3. The Virginia Highlands as a Temperate Zone Agroforest

Detailed plans have already been published to establish Climate Change Haven Communities across the 39 counties of the Virginia Highlands [22] [23]. The goal is to establish sufficient agroforestry food production to support 2.3 million persons. The current population of the 39 counties is sparse and centered in only a few towns in each county. It is estimated that approximately 2,000,000 additional persons could be accommodated as migrants from severely climate-challenged areas of the United States. If the in-migration project is successful, it could be expanded to the entire Appalachian Mountain Region, enabling large-scale in-migration by climate-endangered Americans.

However, because of the limited land area in the total Appalachian Region, it is doubtful that any climate migrants from outside the United States will be able to be accommodated within the Appalachian Region. This stark reality will likely

hold true for temperate Climate Change Haven Community countries across the globe, as well, e.g., Germany, France, Scotland, Scandinavia, and Austria in Europe. As shown in Figure 5, China also may be unable to accept migrants from outside its national borders, once Chinese citizens have been re-located to internal Climate Change Haven areas of the country [24] [25].

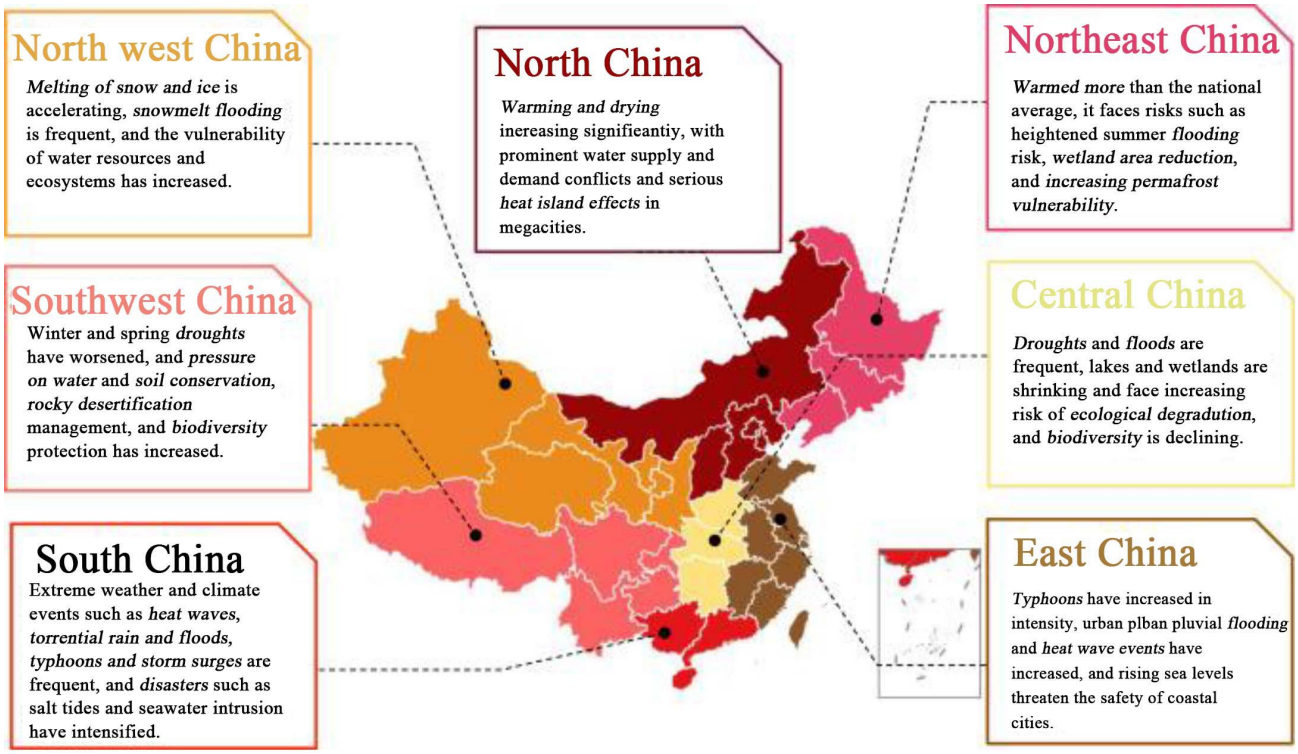

Figure 5. Climate change impacts on China.

4. Climate Change Haven Counties in the Virginia Highlands

There are 39 mountainous counties in the Virginia Highlands Region; each of these can be used to support large-scale agroforestry activities due to their current forestation density and temperate climates. A small portion of this land is currently taken up by lakes, reservoirs, and existing towns. In each county between two to three existing towns are scheduled to be transformed into Climate Change Haven Communities [14] each housing 25,000 to 30,000 residents. This population expansion will reduce the land area available for agroforestry by perhaps 15%.

There are some on-line articles available which calculate the acreage needed to support people using agroforestry methods. Their estimates range from one acre to three acres per person [26] [27]. However, these estimates are untested and their reliability is unknown.

The present study assumes the total number of residents that can be adequately supported within the Virginia Highlands Communities will be between 2,100,000 and 2,300,000 persons. Once that population density is reached, it will be neces-

sary to prohibit further inflow to the Virginia Highlands Region, as the agricultural system will likely not support it. The counties located in the Virginia Highlands Region are listed below.

Counties of the Virginia Highlands Region

Lee, Scott, Wise Russell, Buchanan, Washington, Tazewell, Grayson, Wythe, Bland, Carroll, Pulaski, Giles, Patrick, Floyd Montgomery, Henry, Franklin, Craig, Allegheny, Bottetort, Bedford, Amherst, Rockbridge, Bath, Highland, Augusta, Nelson, Albemarle, Green, Rockingham, Shenandoah, Frederick, Warren, Clarke, Madison, Loudon, Culpepper, Rapahonac.

Creating a Sustainable Food Supply Using Agroforestry

The Virginia Highlands have a very desirable topography upon which to create a sustainable agroforestry food supply. The entire region features mid to tall mountains and foothills, the majority of which are forested with interspersed grassy meadows and fields, as shown in Figure 6. Several of the existing fields are located on steep hillsides which make them unsuitable for traditional flat-field farming methods. However, this feature is very desirable for agroforestry using terracing, alley cropping and forest farming methods. The terracing method is discussed below.

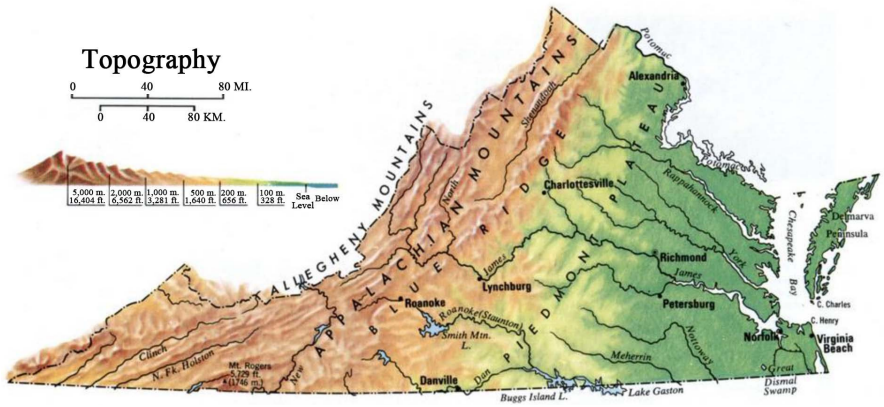

Figure 6. Topographical map of the Virginia Highlands (in striated brown).

5. Terracing

At present, terracing is most commonly used in China and Southeast Asia, where the primary crop raised is rice [28]. However, the terracing method is also suitable for temperate zone crops such as berries, vegetables, legumes and fruits. Essentially, terracing involves forming a series of flat-step terraces up the side of a steep hill. The external edges of each terrace level are trimmed with hedges and/or berry bushes. This prevents the inner terraced crop of vegetables from being swept away during intense rain storms due to climate change [29]. This design is shown in Figure 7 below. Figures 8 and 9 below depict terracing in mountainous terrain found in the Virginia Highlands.

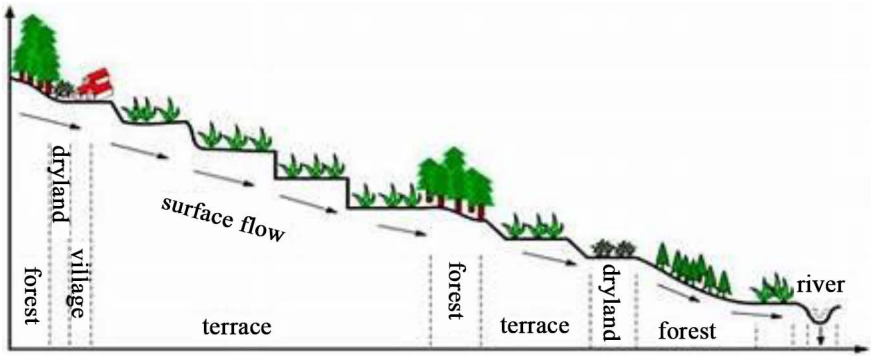

Figure 7. Diagram of terrace farming.

Figure 8. Terrace farming in the Appalachian Mountain Region.

Figure 9. Additional terrace farming in the Appalachian Region.

6. Alley Cropping

Alley Cropping is another agroforestry method; it is especially useful on low hills and flat areas which may flood during heavy rainstorms or become windblown during droughts. With alley cropping, rows of trees are used to create separate areas of crops, such as vegetables, corn, melons, berries and legumes. The trees may be either in a single row or a wider column. The preferred trees for this method of agroforestry are nut and fruit bearing species, such as walnuts, pecans, apples, and peaches. This enables both the tree crop and the alley crop between them to be harvested using traditional farm equipment [30]-[33].

Figure 10 below depicts alley cropping in Central Appalachia and would be appropriate for feeding the Climate Change Haven Communities in the Virginia Highlands, as well as similar terrains globally.

Figure 10. Alley cropping agriculture in Central Appalachia

Figure 11 below shows a different type of alley cropping in which not only trees and vegetables are cultivated, but there is also a grazing area set aside for farm meat animals such as cattle, sheep and pigs. This model is applicable throughout the Virginia Highlands and the Appalachian Region. It could also be extended to many of the northern and central EU countries. This agricultural model is already being widely employed in China [34].

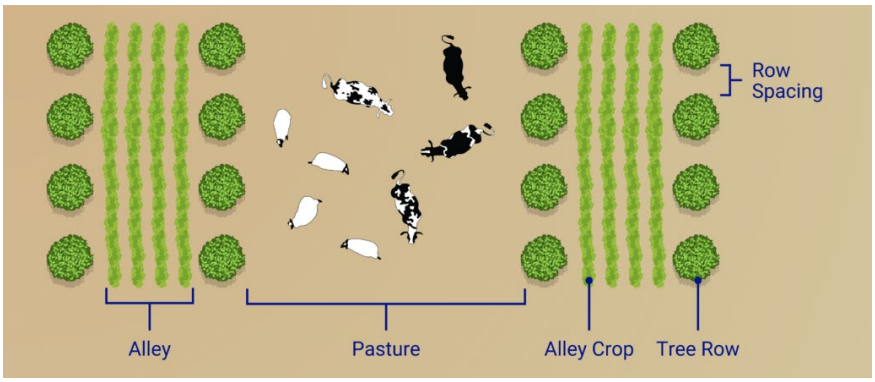

Figure 11. Alley cropping agriculture supporting both vegetation and meat animals.

7. Forest Farming

A third type of agroforestry is termed forest farming. Using this agricultural method, high-value forest crops are grown under a canopy of protective trees. Figure 12 below depicts a multi-crop example of forest farming. Currently forest farming is being primarily used in the United States to produce high-value herbal and root crops such as ginseng, mushrooms, truffles, ramps, and watercress.

However, for the present purpose of helping to provide nutritional support for incoming American migrants, forest farming activities in the Virginia Highlands Region will be primarily directed toward food production with an emphasis on wild honey, tree syrups, tree nuts, berries, and edible fungi [35] [36].

Figure 12. Forest farming with multiple crops.

Food Plant Species Appropriate for the Virginia Highlands Region

Subtropical fruits (shown in Figure 13 below) are a diverse group that thrive in the warmer regions of the world, typically between 23 and 30 degrees latitude in the northern hemisphere. Most of the Virginia Highlands Region is able support these fruits now, and with forecast global warming, all 39 counties should be able to produce these fruits by 2030.

These plant species are recognized as having unique flavors, aromas, and high nutritional values [37] [38].

This will enable the fruit to be distributed across the Climate Change Haven Communities and be consumed for an extended time period during the year. Specific fruits can be grown in the counties best suited to their cultivation. Examples include avocadoes, mangoes, kiwi fruit, pineapple, olives, bananas, papaya, guava, grapes, passionfruit, dragon fruit, starfruit, and persimmons.

Figure 13. Subtropical fruits appropriate for the Virginia Highlands.

8. Berries

The Appalachian Region has long been recognized for the diversity of its berry production [39], many of which have been used historically to produce local wines. Available species in the Virginia Highlands Region include: blueberries, blackberries, red and black raspberries, wineberries. strawberries, huckleberries, elderberries, mulberries and a wide variety of wild grapes, e.g., muscadine. These berry bushes would be ideal for trimming the outer edges of terraced mountain sides.

9. Nut Trees

Nut trees native to the Virginia Highlands are listed below in Figure 14; all provide storable, protein-rich nutrients. These nut tree species are appropriate for placement in the alley cropping agroforestry plan described earlier.

NUTRIENT COMPARISON CHART FOR TREE NUTS

Based on a 28-gram portion.	ALMOND	BRAZIL	CASHEW	HAZELNUT	MACADAMIA	PECAN	PISTACHIO	WALNUT
CALORIES	163	186	157	178	**204**	196	158	185
PROTEIN (G)	**6.0**	4.1	5.2	4.2	2.2	2.6	5.8	4.3
TOTAL FAT (G)	14.0	18.8	12.4	17.2	**21.5**	20.4	12.6	18.5
SATURATED FAT (G)	1.1	**4.3**	2.2	1.3	3.4	1.8	1.5	1.7
POLYUNSATURATED FAT (G)	3.4	5.8	2.2	2.2	0.4	6.1	3.8	**13.4**
MONOUNSATURATED FAT (G)	8.8	7.0	6.7	12.9	**16.7**	11.6	6.6	2.5
CARBOHYDRATES (G)	6.1	3.5	**8.6**	4.7	**3.9**	3.9	7.9	3.9
DIETARY FIBER (G)	**3.5**	2.1	0.9	2.7	2.4	2.7	2.9	1.9
POTASSIUM (MG)	200	187	187	193	104	116	**291**	125
MAGNESIUM (MG)	76	**107**	83	46	37	34	34	45
ZINC (MG)	0.9	1.2	**1.6**	0.7	0.4	1.3	0.6	0.9
COPPER (MG)	0.3	0.5	**0.6**	0.5	0.2	0.3	0.4	0.5
VITAMIN B6 (MG)	0	0	0.1	0.2	0.1	0.1	**0.5**	0.2
FOLATE (MCG)	14	6	7	**32**	3	6	14	28
RIBOFLAVIN (MG)	**0.3**	0	0	0	0.1	0	0.1	0
NIACIN (MG)	**1.0**	0.1	0.3	0.5	0.7	0.3	0.4	0.3
ALPHA-TOCOPHEROL (MG)	**7.4**	1.6	0.3	4.3	0.2	0.4	0.7	0.2
CALCIUM (MG)	**75**	45	10	32	24	20	30	28
IRON (MG)	1.1	0.7	**1.9**	1.3	1.1	0.7	1.2	0.8

28 grams = 1 ounce
8 ounces = 1 cup

Source: USDA Nutrient Laboratory Database, Release 20. The bold orange number indicates the highest value.

Figure 14. Nutritional value of various nut crops grown in the Virginia Highlands.

10. Legumes

Another valuable source of protein and other nutrients harvestable in the Virginia Highlands are legumes which are listed in Figure 15 below. Many of these species are already available throughout the Virginia Highlands Region and can be quickly expanded using terraced agroforestry.

Figure 15. Nutritional values of legumes harvestable in the Virginia Highlands.

Expanding the availability of the above-named fruits, vegetables, nuts and legumes using sloped-field terracing, alley cropping and forest farming within the Virginia Highlands Region will likely be nutritionally sufficient to feed the antic-

ipated total population of 2,100,000 to 2,300,000. However, current residents of the Virginia Highlands Region are strongly carnivorous and would not be happy restricted to a vegan diet. Similarly, incoming migrants from the Western US states, Texas, and the Gulf Coast would also greatly desire meat along with their healthy vegetables, berries, fruits and nuts [40].

To respond to this consumer dietary preference, a second study is now being conducted on expanding existing cattle, sheep, hog and poultry farming in the Virginia Highlands Region using eco-sustainable methods. Simultaneously, large, private land-owners will be given financial and zoning incentives to stock their woodlands with elk, mountain bison and deer. These three species are historically native to the Appalachian Mountain Region, and have been recently re-introduced across the Virginia Highlands by the Virginia and Federal US Government Forestry Services [41]-[43]. However, there are strict procedures in place for hunting these animals on public land. By creating privately-owned herds of these game animals throughout the Virginia Highlands Region, a sustainable and healthy meat source can be provided to the enlarged population of the Region. This plan will be presented in detail in a second study.

11. Discussion

In developing this agroforestry strategy for creating a sustainable food supply in the Virginia Highlands Region, the intention has been to illustrate that such plans are feasible within the time frame confronting the world. It should be possible to extend the agricultural practices described here to several other temperate regions of the globe. To do so will require immediate global efforts to maintain and extend, if possible, temperate forests. These forests are essential to the survival of millions, likely billions, of persons [44]-[46].

To halt forest destruction, countries and global institutions such as the United Nations, should undertake communication efforts to halt the practice of monocropping and educate farmers and large-scale industrial agriculturalists to switch to agroforestry methods. Analogously, consumers world-wide need to be educated to understand the need for purchasing agroforestry food products, instead of selecting items grown using industrial farming methods.

There is a second, very troubling issue raised by the research reported here. Across the Virginia Highlands Region it is estimated that around 2,000,000+ additional persons can be accommodated in Climate Change Haven Communities. The Appalachian Mountain Range in total contains approximately 205,000 square miles. Thus, it would be forecast to support approximately 25,000,000 persons.

Assuming that the same estimates hold for other temperate zone mountainous areas of the world, this would leave many persons – especially those from the most climate-endangered areas near the equator—unable to emigrate to these safer areas, because temperate zone countries will need the space for their own citizens. This conundrum is highlighted by the situation now facing many European Union countries.

In the EU, northern countries such as Sweden, Norway, Austria, and Germany will soon be (and already are) receiving requests from southern EU countries such as Spain, Portugal, Italy, Greece, Cyprus, and Bulgaria to accept their citizens as migrants. Some applicants will be able to be accepted; the acceptances will likely be made to southern EU migrants who are well-educated, have desirable technical skills and/or are middle class and above in income [47] [48]. However, many other applications will be denied. This challenge, in and of itself, may seriously weaken the political stability of the European Union.

12. Conclusion

The expansion of agroforestry food production methods is very likely the global best hope for preventing further deterioration of the Earth's climate. By expanding its use across the temperate, mountainous climates of the world, humans will likely have the best chance of not only surviving climate change, but also of slowing, perhaps even halting, its relentless progress. The United States, where this present study is based, is currently the least motivated politically to enact the necessary changes to its domestic agricultural system. Perhaps if more progressive countries, for example the European Union or China, successfully shift their agricultural systems to terracing, row cropping and forest farming, it will serve as a model for American agriculture to emulate.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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