Sustainable Development: Intercropping for Agricultural Production

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Abstract

The damaging effects of monoculture threaten the sustainability of our world. Genetic engineering, or biotechnology, gravely endangers the future integrity of genes with possible unforeseen mutations. For example, Monsanto has created a terminator technology that will not allow farmers to reproduce their own plants from secondary seeds. This minimizes the diversity of plant crop varieties by which farmers have relied upon for centuries. Biotechnology may thereby cause irreparable damage to the sustainability of the world's food supply. Although all biotechnology is not wrongful, most genetically engineered crops are potentially so dangerous that even insurance companies will not cover farmers that use them.

Furthermore, the introduction of patent clone seeds will undermine the ability of rural farmers to compete for survival by raising prices on conventional seeds. This corners decision making into acceptance of the same crop cultivation. Environmental effects are devastating as more pesticides and herbicides are used for these plants, and resistant pests may abound.

In addition, exponential population growth in cities presents the problem of land availability. The trick is to make the maximum use of space while balancing the environment. The beauty of intercropping is that many types exist so that specialization for different climates and terrain may be applied to a particular region. Research shows successful results with intercropping. Organic farmers often have superior net cash returns, making it a feasible option for mass production.

Finally, environmental engineers need to know their roles in sustainable development. There are many resources that university professors can use to teach students and/ or prospective students in engineering about agriculture including textbooks and ASEE's website. Sustainable development is a hot topic in many engineering programs and intercropping is one component of it that should not be overlooked.

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Introduction

With more than 800 million people starving to death [1], a revolution in agricultural practices is needed to secure food production with sustainability and preservation of the environment. Current applications of biotechnology gravely endanger the future integrity of genes with possible unforeseen mutations. Investments in new technologies are much needed to confront these problems. An alternative to the damaging effects of monoculture is intercropping.

A number of solutions can be implemented in order to combine different areas of interest for a common goal. Engineering advances, through the use of even the most basic formulas, may brighten our socioecological future with a confident sense of economics. It is highly important that current engineering students are introduced to the methods of agricultural and biological engineering that are described in this paper. The world's population grows rapidly while its resources deplete just as quickly. If engineering students are introduced to innovative methods of agricultural and biological engineering early on, some may decide to pursue a career in these fields. These students should be exposed to creative methods of sustainability that reverse the current effects of monoculture. It is especially critical that environmental engineering students be introduced to intercropping as they may very well be called upon to deal with such issues in sustainable development.

This paper will review ways to integrate intercropping for sustainable development into an engineering curriculum. It will also cover the various components of this topic. Additionally, it will explore solutions to inspire creative development in future engineers.

Integrating intercropping into engineering curriculum

Before the various components of intercropping for sustainable development are discussed, it is important to understand when and how it is appropriate for the topic to be integrated into the engineering curriculum. The extreme relevance and importance of this topic was first brought to the attention of faculty at Middle Tennessee State University last year during an upper level course called Pollution Control Technology. This course is required for students majoring in Environmental Science and Technology, which is an interdisciplinary major in which students are required to take classes from a variety of disciplines, including biology and chemistry. Last year one student gave a presentation on intercropping techniques for sustainable development during the last two weeks of the course that are reserved for special topics. The class got into a heated discussion about the importance of the topic and many of the students as well as the professor felt that it was something that should be included in the curriculum. As a result, it was decided that intercropping techniques for sustainable development should become a permanent part of the syllabus of Pollution Control Technology that would be addressed in the special topics section of the class.

This topic being of such great interest to the students in this class combined with the grave importance of the topic led to the consensus that freshman students majoring in

Environmental Science and Technology from this year forward would be introduced to intercropping techniques for sustainable development in their Introduction to Environmental Science and Technology class. Additionally, the topic is being addressed in the students' two required one hour seminar classes. Finally, by covering the subject of intercropping in Pollution Control Technology, students majoring in Engineering and Engineering Technology are exposed to it as well.

Sustainability

"Sustainable agriculture does not deplete natural resources, use harmful or artificial substances that accumulate in the environment, so it can be applied indefinitely without harming the environment" [2]. Proposed guidelines of sustainability are as follows:

"(1) Maintaining or increasing productive levels over time;
(2) Reducing chemical inputs and minimizing pollution while maintaining aquatic systems;
(3) Sustaining output levels with climatic or economic changes, e.g., price changes, climatic disturbance, through vegetative modification, or the effective use of biodiversity;
(4) Encouraging biological cycles with agroecosystems, e.g., microflora and fauna; and/or
(5) Minimizing the ecological consequences on surrounding ecosystems" [3].

Land availability

Exponential growth of the human population presents the problem of land availability for feeding ourselves while protecting the very nature that sustains us. Forested land is cleared for crops, reducing biodiversity and promoting degradation of the soil. In many tropical areas, crops grown after the slash and burn method may only grow for one year before rendering the ground useless. With half of the world's natural reserves being used for agriculture, present rates predict the extinction of half of all remaining species over the next half a century [4].

Monoculture

In temperate zones such as ours, a monocultural field (one in which a single species is grown) is the method of choice for structural ease in production. But excess soil tillage releases carbon dioxide and nitrous oxide (major greenhouse gases) [5], and it also reduces the microflora and fauna that increase soil productivity [3]. The application of chemical fertilizers and pesticides contaminates our water supply. Increasing amounts of groundwater toxicity from some of the agricultural regions in the U.S. is so high that children under ten years of age have received their maximum "life dose" allowance of these contaminants. And "thousands of farm workers contract chronic health problems or die from the chemicals every year" [6]. The carcinogenic effects of the residues in our food may even be enhanced by the combination of some of these chemicals [6].

Biotechnology fears

"Many scientists believe that genetically engineered organisms have been released into the environment and food supply without adequate testing" [7]. Many countries have banned the admittance of biotech foods for fear of harmful or even deadly consequences. "Farmers who have used this new technology may be facing massive liability from damage caused by genetic drift, increased weed and pest resistance, and the destruction of wildlife and beneficial insects" [7]. Many farmers are demanding that the government suspend the spread of genetically altered seeds and products until further notice [7].

Biotechnology patents

The patenting of biotech seeds is a problem in itself. Monsanto and DuPont/Pioneer are two corporations that control the seed trade in the U.S. Seed bought from Monsanto, for example, may be grown under contract [7]. The cultivation of a second generation of seeds from the plant is not [8]. Many cases have been taken to court for breach of contract, yet the sale of patent seeds is encouraged by the raised price of conventional ones [7]. The inability of many farmers to buy a safer, more expensive seed is therefore a major contributor to the genetic cleansing of natural variety types.

Terminator technology is patented and, fortunately, unused as of yet. It is a complex system using several different control genes that when used in conjunction with tetracycline, the target crop variety will produce infertile seeds. Widespread use of tetracycline-treated seeds would enable resistant microorganisms to evolve and become widespread as well [9]. Also, the impossibility of a farmer to save and plants his seeds is an outright precursor to starvation.

Devastating effects of biotechnology

Imprecision of genetic engineering makes it a target of concern. The actual insertion of a gene into DNA is random, and may disrupt unknown essential functions of other genes. Widespread crop failure could ensue as a resistant pest, fungus, or virus preys on the identical genome of an entire field. Cross-pollination of biotech plants with natural crops is possible with airborne vectors such as insects, birds, and wind. It is impossible to recall bacteria and viruses once released, so negative effects may be irreversible [8]. Some insurance companies are refusing farmers who intend to grow genetically modified crops for fear of future risks and liability [10].

Beneficial effects of biotechnology

Not all aspects of biotechnology are bad. When used in the right way, biotechnology may serve useful purposes without upsetting the environment. Endangered species may be recovered in a gene bank with frozen tissue samples taken from many individuals.

Microbes may be engineered for pollution cleanup and waste removal. Bioremediation may be achieved with natural or recombinant microorganisms to break down toxic substances [11]. Rice enhanced with vitamin A may save people from blindness in rural areas of Asia. Also, two particular silk proteins have been transferred to cells derived from cow udders and cultured within Petri dishes. Upon being sent in solution through specialized nozzles, these proteins self-assemble themselves to form a complex that is stronger than steel. In the near future, steel mining may become a thing of the past [9].

Intercropping

Global devastation from reckless agricultural land use may be counteracted with an ancient practice called intercropping. Designated planting intervals of certain species of perennial and annual plants allows for symbiosis and ample sunlight [12]. Nitrogen fixation takes place in tree roots due to the presence of soil microorganisms converting atmospheric nitrogen into a usable form for the plant. Fixed nitrogen facilitates fast growth and high production, and may be transferred to agricultural crops. This reduces or eliminates the need for excessive fertilizers [3].

Types

Many types of intercropping, or agroforestry, exist so that specialization for different climates and terrain may be applied to a particular region. Taungya is where crops are grown amongst young tree stands for the first few years in order to provide an immediate income from the crops. Wide-row intercropping, or alleycropping, allows space for machinery. Shade and nurse trees accommodate shade-loving crops like coffee, tea, and cacao. Fodder banks are close rows of pruned trees used to feed livestock. Rotational woodlots are harvested every so often for a larger harvest of wood for fuel and other needs [13]. Guilds are combinations of various crops like fruits and root crops in stacked arrangements in order to maximize the amount of available solar energy. An example of a guild is a banana tree with beans, beets, and poppies growing together so that the vines may climb the trees while the top of the ground and undersurface of the soil are occupied by crops [14]. Strip intercropping combines several crops in wide strips [13]. Along stream banks and waterways, riparian buffer zones are used to hold land in place against the force of currents. Barrier trees may be planted in extremely windy areas to protect the soil, plants, and water moisture [12].

Methods

Tree canopies may be managed to reduce shade when needed through a process called pollarding. To optimize productivity via species-specific symbiosis and function, certain species may be selected and planted according to the particular inclination of the environment [3]. In a case study done in California, broccoli and lettuce were grown together since broccoli has deeper roots and a longer growing season, while lettuce has shallow roots and grows more quickly. The coexistence conserved land and water resources and resulted in overyielding, a process in which a greater yield is obtained from the same amount of land in an intercropping system rather than monoculture [15]. Some methods may be used to improve performance based on the location of the farm. For instance, plants in desert conditions may be first stabilized by drip irrigation and gradually adapted to the harsh climate, as the constant water supply is removed [12].

Pest control

Pests are controlled much easier due to the distraction of intermittent neighboring plants to block further entry into the fields. The type of crop grown in the vicinity of the pest target also cuts down on invasion. Nasturtiums, a flower, may be grown around cabbage to distract butterflies that eat them. Coriander deters aphid attacks on potatoes [14]. A publication by Preston Sullivan entitled Applying the Principles of Sustainable Farming explores, among all other benefits of intercropping, the practical alternatives of pest control for enhanced ecology and minimal environmental damage. These include natural pest predators, immediate discouragement from different rows of host plants, and the vital role of IPM (integrated pest management) systems. IPM systems apply combinatory effects of "habitat modification and cultural, physical, biological, and chemical practices to minimize crop losses" [16]. Appropriate measures can be taken to alter the relationship of a pest to its environment once its life cycle is monitored and understood. Delayed planting dates and crop rotations are examples. Of course, if all else fails, "biorational" pesticides may be used in place of broad-spectrum types. These may be derived from natural plant sources or contain the least amount of toxicity that is short-lived for biodegradation and greatly reduced risk for side effects [16].

Habitats

Aesthetically, trees sparsely decorating the landscape mimic the natural appeal of the ecosystem and preserving them helps reduce climate changes [17]. They may serve as a bridge between zones of isolated habitats for endangered species as well. Many animals need migration and are inhibited by their protected areas being surrounded by farmland. There are about six hundred gorillas left in the mountaintops of Africa, which are reduced to islands in a sea of cropland. Agroforestry methods have been used in order to combat this problem. For example, buffer zones protect rhinos and tigers in Nepal while windbreaks in Costa Rica form wildlife corridors through dairy farms [4].

Biofuels

Biofuels for energy are grown from corn, perennial grasses, and short rotation wood crops like poplars. These have great market potential as an alternative to fossil fuels. Lands growing these biomass crops may be located on marginal lands and restore land from agricultural disturbances [15].

Economic benefits

Research shows successful results with intercropping. Organic farmers often have superior net cash returns [6], making it a feasible option for mass production. Productive

Conservation: Growing Specialty Forest Products in Agroforestry Plantings by Scott J. Josiah highlights important economic potential for multipurpose woody plants that can be grown in any convenient setting [18]. Improved cropping practices with trees may yield even three times the amount of corn and rice compared to traditional monocultural fields [19]. In the aforementioned case study with broccoli and lettuce intercropping, the yields were 10-36% greater. Also to be taken into account are the conserved resources and reduction in tillage and weeds [15]. The monetary rewards of intercropping are relative to many factors, not yield alone.

Rubber trees

The positive socioeconomic relationship with agroforestry is exhibited with rubber tree plantations. While the trees themselves are productive resources, the land beneath them is able to teem with life. Because of soil types and climates, some crops will do better than others. A wide variety of crops were found to do well, whereas others were not. Rubber plantations with sweet potatoes, maize, sorghum, cassava, peanuts, etc. for eight years showed no return for investment, but the economic benefits showed quickly and the villagers were able to plant and sow each year [20]. “Economic tea, coffee, pepper, sugarcane, lemongrass, and sisal hemp were harvested the third year, with harvests lasting over 5 years [longer than monocultural plantings] with great economic benefits. It is used prevalently in South China now” [20].

Paulownia

The paulownia tree is a considerable species for increasing income for rural people. A ten-year-old tree can produce 100 kg of dry branches for fuel wood. It grows very fast, works well with many crops, and its beautiful, light, wood can be used for most lumber requirements. The leaves, flowers, and bark have medicinal properties. The leaves are rich with protein, carbohydrates, and minerals, so it makes terrific fodder for livestock. Sparsely oriented branches and leaves allow lots of light for underlying crops, while its deep, confined rooting system ensures compatibility with other plants’ roots. Wind is reduced up to 20-50%, thereby increasing air moisture. Plantings of 40-67 trees per ha increase yield of wheat, corn, cotton, and millet, but not sesame and sweet potato [21]. The International Farm Forestry Training Centre has trained hundreds of managers and policy makers from a variety of countries in paulownia intercropping since 1991. “Professor Zhu’s farm forestry project has planted 900,000 ha with paulownia, bamboo, Chinese fir, and other tree varieties, boosting annual rural earning by about $20 million (1995)” [22].

Tropical project

One particular project of intercropping takes place in the tropics of south India. Severely damaged land was rehabilitated in Auroville, an international community. The starting point was at the level of desertification. Work began at stage one to halt erosion by forming microcatchment areas to hold rainwater for percolation. Checkdams and catchment ponds improved retention for ecological replenishment. Stage two began reforestation to stabilize the soil, conserve moisture, and provide sustenance by tapping deeper nutrient reserves with perennial root systems. This was achieved with mixed plantations of shrubs, grasses, and trees. Thorny hedges protect seedlings from invasion of livestock. In stage three, tree growth becomes prolific, and uses abound such as windbreaks. Livestock may be introduced for fertilization as well as product. Crop rotation and intercropping with leguminous species also increases soil fertility. Stage four balances the surroundings with micro-climate and agroforestry. Maturation of the symbiotic relations between integrated plants and animals forms a sustainable area for humans to live. Not only is it practical and productive, it is also beautiful. After two decades, Auroville has become a large botanical preservation for hundreds of endangered and rare species. Outreach programs here and elsewhere have increased activities between foresters and farmers to enrich village projects and meet environmental standards [23].

Climate change

Climate is greatly affected by the land-use changes of forests and agricultural practices. A study funded by NASA reveals that these disturbances may play a larger role in climate change than greenhouse gas. This is due to the redistribution of heat as it leaves a depleted source of pre-existing containment, such as all the trees in a forest being cut down for crops. Moisture that was there is not replaced in monoculture. In a different study, 80 percent of the some odd 1,500 species of plants and animals monitored from all over the world have been found to shift their patterns with the projected climatic changes. Range limits for 99 species had moved toward the north by an average of 6 km per decade [17].

Carbon sequestration

"Politicians in several countries- particularly those that stand to benefit, such as Japan, Canada, Australia, and the United States- have responded enthusiastically to the idea that the role of natural phenomena such as forests in storing carbon can be enhanced, thus counteracting the effects of CO_2 emissions arising from the use of fossil fuels" [24]. "The simplest way to sequester carbon is to preserve trees and to plant more. Trees, especially young and fast-growing ones, soak up a great deal of carbon dioxide, break it down in photosynthesis, and store the carbon in new wood" [4]. There are reforestation projects initiated by many companies and governments globally, such as the AES Corporation, World Resources Institute, and the relief agency CARE that have joined forces in Guatemala to teach locals about tree-farming practices with the community woodlots they created."The trees planted are expected to absorb up to 58 million tons of carbon dioxide over 40 years" [4].

Governmental incentive

The suggested policies within the Kyoto Protocol were formulated under the expectations that the greenhouse gas emissions of the most industrialized nations could be reduced in 2012 by 5% of their levels in 1990. The goal was thought to be too costly by President Bush in 2001, renouncing the treaty and leaving most countries waiting for U.S.

ratification. Trees sequester CO_2 during photosynthesis (a process basically free of charge). However, decreasing forests and increasing CO_2 levels compromise the ability of plants to filter the air as much as possible. The U.S. Initiative on Joint Implementation and "Climate VISION" (Voluntary Innovative Sector Initiatives: Opportunities Now) encourage the cost-efficient strategies of sequestration in reducing greenhouse gas emissions [4]. Agroforestry and clever strategies in intercropping should be administered generously both commercially and among simple undertakings of projects worldwide.

International efforts

Basic research and international effort is urgently needed to correct the flawed habits of the farm. In 1985, the ICRAF (International Center for Research in Agroforestry) and the South African governments of Malawi, Tanzania, Zambia, and Zimbabwe formed a network with the goals of alleviating rural poverty and meeting basic human needs with methods including multipurpose tree improvement and management. A five-year project (2002-06) of the CIDA (Canadian International Development Agency) is using new methods of intercropping with low-cost technologies. The CIDA is using conferences, research programs, and workshops with universities and farmers for the education and spread of agroforestry. Zambia research shows that *Sesbania* inter-planting yields a 250% increase in maize and 12 tons of firewood per hectare per year. It is "expected in 2010 that 2.0 million small-scale farm families in Southern Africa will have been reached with agroforestry innovations" [25]. Less than 6% of Northern Ireland is forested, so agroforestry is now being used for enhancing habitat and landscape. Sycamore and ash trees growing in sheep pastures are part of the UK National Network Silvopastoral Experiment, regulated by students from Queens University [26]. In 1990, 75% of the reforestation area in Java, Indonesia utilized intercropping with trees [16]. The American Forest and Paper Association with the U.S. department of Agriculture have initiated 114 million acres to reduce greenhouse gases by 12% by 2012. It is the world's largest program for sustainable forestry [27]. The National Association of RC&D Councils (NARC&DC) Report: RC&D Survey of Agroforestry Practices is a summary of the National Association of Resource Conservation and Development Councils from 1999 that contains maps and graphs of agroforestry used within the United States. It addresses project involvement and opportunities with further application possible for landowners and agencies [28].

Engineering

A few basic equations and concepts of intercropping listed here may be used and expanded upon by the experience and expertise of environmental engineers. Together with more creative solutions, the quantitative and qualitative structures of this design may provide a great system of opportunities for the specialization of essential components underestimated by current applications of monoculture.

Land equivalent ratio

The land equivalent ratio (LER) = (Yab/Ya) + (Yba/Yb), where Ya and Yb are monocultural yields of two different crops. Yab is the output of species (a) grown with (b), and Yba is the output of species (b) combined with (a). With basic LER comparisons, if the ratio value for plant-plant combination is greater than 1, the proposed polyculture is superior to the monoculture of the primary species. If the comparison ration is less than 1, monocultures are the better option [3].

Competitive production

When two crops share and compete for the same resources, they may exploit the resources more efficiently than a single species. This is called competitive production, resulting in greater productive gains than a single-species system and having greater LER values. Two separate components are 1) competitive acquisition, the efficient interception of resources by the plants, and 2) competitive partitioning, the efficient use or conversion of the resources into usable outputs [3].

Competitive acquisition with interception gains is the principle that the introduction of more species per area improves opportunities of an area's potential for interception of sunlight, rainwater, and nutrients. Three types are as follows:

> 1) Sequential interception is when the growing seasons and resource needs of the two species are separate.
> 2) Semi-sequential interception is where the species overlap in their growth duration, separating peak demand for specific resources.
> 3) Simultaneous interception is where plants share the same growing season, but resource needs occur at different times within the period [3].

Intercropping field trials show most productivity when component crops differ greatly in their growth duration. For example, planting dates can control timing, as one species may enter a period of rapid growth earlier than the other. Woody perennial selection of a tree species such as *Faidherbia albida* is a very successful intercrop because seasonal growth is sequential or semi-sequential with many annual crops [3].

Exclusive physical access deals with separate zones of root and canopy architecture. Roots of certain species are present in different soil strata, and may be compatible and less competitive when planted adjacent to plants with root zones other than its own. The canopies of trees are also considered for maximum use of solar energy and the needs of the underlying crop. Wide canopies intercept more vertical, or midday, light. Tall, elongated canopies capture more horizontal, or early morning and late evening, light [3].

Competitive partitioning with conversion or marginal gains in many cases equates efficiency to the amount of used resource it takes to produce a unit of output. For polycultures, multiple species each can receive less resources and produce more output (in LER measure). Spatial allocation, through distribution of resources, regulates growth and yield. The more efficient the distribution, the greater the marginal gain. Conversion gains not only result when resources are used more efficiently to produce a harvestable output, but also when a lower amount of a resource produces less of, but better quality output [3].

Cost equivalent ratio

Cost Equivalent Ratio (CER) compares basic costs, where Ca is the monocultural costs per area and Cab are the polycultural system costs. CER = (Ca/Cab) (LER). If Ca = $2 and Cab = $1, crude CER= 2.0, indicating with per unit of management inputs, the more complex system gives twice the per area output than obtainable with a monoculture of the primary crop. If the LER is 0.75, then the CER based on LER will be 1.50. When management inputs are considered, the system achieves significant gains [3].

Solutions

A large number of solutions may be available with the promise of monetary gains and practical uses possible with intercropping with trees. Unused land in cities may be eloquently filled and landscaped with pollution resistant trees and a number of ornamental herbs, crops, and shrubs like berries can be used in place of other purely decorative species. Fines paid by environmentally harmful industries could be funded towards projects that give a percentage to landowners who enhance degraded land with innovative natural technologies such as agroforestry for food provision and reforested landscapes. Deer and other wildlife problematic to highway traffic may be inhibited from crossing by planting a combination of rows of high-density woody perennials. Buildings could be partially transformed into greenhouses by making entire or partial roofs and walls out of materials optimal for light and heat absorption so that a special arrangement of plant species may contribute to oxygenated indoor air and even remove harmful particulates of pollution linked to allergies. With these buildings, if the summertime heat became too great, either outdoor deciduous trees could shade the building (allowing for wintertime heat instead) or the heat could be redirected into a form of energy conversion. The wind tunnel effect that is present through and around open spaces of specifically located trees [3] can be harnessed, encouraging energy production from windmills as well as providing a sound barrier from its facilitation. Many types of engineers, such as civil and architectural engineers can facilitate these types of projects. This is why it is so crucial that all engineering students be educated in this subject matter.

Integration Importance

Biology, agriculture, and engineering should not be kept as separate entities. Engineering design is a gift that, when given toward much needed arenas, formulates the structural basis for furthering mankind. Without the calculated precision of engineering, society will not be able to progress. Technical advance can sometimes complicate the mechanisms of survival, so that simplistic endeavors should not go unnoticed. The old adage "less is more" can be invaluable in unraveling a problem's complexity. Basic techniques in agricultural practice should be enhanced, but not genetically reduced.

Engineers have a great ability and role to play alongside farmers in developing the right formulas for equal food distribution throughout our world's hungry populations.

Conclusion

Sustainable development in agricultural production is an issue that requires a unified cooperation of the entire international community. Through a unique collaboration of resource management skills, technological ingenuity, and engineering education, engineering advances will potentially enable developing countries to enjoy continued economic growth and social productivity while reducing or eradicating the sources of environmental distress.

First and foremost, the future of sustainable development in agricultural production needs to be secured by ensuring that topics on the subject, including intercropping, are included early on in an engineering student's education. A perfect place to introduce these topics is in environmental engineering courses, which many engineering students have to take. This could also help undecided engineering students make decisions to major in agricultural and biological engineering or a related field. Additionally, it could help future leaders of other engineering fields make wise decisions to protect the environment and enhance the quality of life for human beings. Further steps in engineering education can also be made through collaboration of universities and industries. Many industrial facilities employ biological and agricultural engineers for activities which can be arranged to foster knowledge in this subject matter. These activities may consist of fieldtrips, independent studies, and internships.

An innovative agricultural style, intercropping is the most positive solution for utilizing limited space. Urban growth will turn most forested areas into concrete or damaging monocultural plots if untreated. Plantings are a simple, manageable way to make sure our woods stay safe in the midst of skyscrapers.

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Biographies

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Olivia Dees is an undergraduate student at Middle Tennessee State University. As a plant emphasis biology major with a minor in environmental studies and technology, she plans to graduate with a career in environmental conservation.