



Performance and Adoptability of
Biodegradable Mulch

biodegradablemulch.org

**GLOSSARY OF TERMS ASSOCIATED WITH BIODEGRADABLE
MULCHES FOR SPECIALTY CROPS**

Carol Miles, Srinivasa Ponnaluru, Suzette Galinato, Debra Inglis, Tom Marsh, Andrew Corbin, Karen Leonas, and Tom Walters¹; Doug Hayes, Bobby Jones, Jaehoon Lee, Larry Wadsworth and Annette Wszelaki²; Jennifer Moore-Kucera³; Russ Wallace⁴; Marian Brodhagen⁵; and Eric Belasco⁶

¹ Washington State University

² University of Tennessee

³ Texas Tech University

⁴ Texas A&M

⁵ Western Washington University

⁶ Montana State University

1. Additive: A substance added to something in small quantities typically to improve or preserve it.[1]
2. Adoption: The “decision to make full use of an innovation as the best course of action available.” The decision to adopt or reject an innovation is the “decision” stage of the “innovation-decision process,” which is the “process through which an individual (or other decision-making unit) passes from first knowledge of an innovation, to the formation of an attitude toward the innovation, to a decision to adopt or reject, to implementation and the use of a new idea, and to confirmative of this decision.” [16]
3. Benefit-cost analysis: The application of discounted cashflow analysis to measure the benefits and costs generated by an investment [44]
4. Biobased: Commercial or industrial products (other than food or feed) that are composed in whole or in significant part of biological products or renewable domestic agricultural materials (including plant, animal, and marine materials) or forestry materials. [56]

5. **Biobased Plastics:** High polymeric materials obtained through chemical or biological synthesis from raw materials. Some share of the carbon atoms in biobased plastics are derived from renewable *feedstocks* (a term defined below) and some fossil-fuel-based carbon. The percentage of *biobased* ingredients and the conditions under which the biobased product may biodegrade, if at all, vary widely. (compare to *bioplastic*, below) [51]
6. **Biodegradable:** Capable of being broken down via microbial activity, as opposed to degradable, which refers to materials that can be broken down by abiotic factors such as heat, UV light, or mechanical stress. Complete biodegradation (i.e., mineralization) refers to the oxidation of the parent compound (an organic molecule) to carbon dioxide and water. Biodegradation provides both carbon and energy for the growth and reproduction of cells. [32]
7. **Biodegradable mulch (other):** Whole plant, plant debris, or plant product such as cover crops, straw, tree bark, wood chips, or paper, that is used for weed control and moisture conservation. Often tends to reduce soil temperatures. Will biodegrade in the soil due to microbial activity. [35] [5]
8. **Biodegradable plastic:** Degradable plastic in which the degradation results from the action of naturally occurring microorganisms such as bacteria, fungi, and algae. [47]
9. **Biodegradable plastic mulch:** Manufactured alternative to plastic mulch. Ideally, biodegradable mulch provides the same benefits as plastic mulch (weed control, soil temperature moderation, reduced soil-borne pathogens, soil moisture retention, and soil conservation) and provides the added benefit of being 100% biodegradable, either in the field, soil or in composting, with no formation of toxic residues. [27]
10. **Biodegradability Standardized Test, Ambient Soil Conditions (ASTM D5988-3):** Standard test method for determining aerobic biodegradation in soil of plastic materials or residual plastic materials after composting. [9]
Requires the following:
 - Requires selection of a common microbe and soil type; soil water activity, pH, etc., controlled.
 - Operated via a dessicator.
 - Biodegradation assessed by comparison to a positive control.
 - CO₂ measured via reaction with Ba(OH)₂, yielding BaCO₃; reactant Ba(OH)₂ concentration determined via titration.
 - Biodegradation can also be monitored through BOD (biological oxygen demand).[48]
11. **Biodegradability Standardized Test, Industrial Composting Conditions (ASTM D5338-98) [9]:** Standard test method for determining aerobic biodegradation of plastic materials under controlled composting conditions that are similar to D5988, except:
 - A specified compositing apparatus is required.

- 2-L reactors with aerators.
 - A robust means of measuring CO₂, such as IR, should be considered.
 - Positive and negative controls are used. [49]
12. Biofumigation: Elimination or suppression of plant pathogens, nematodes or weeds in the soil by amendment with biological products, particularly Brassica plants or seed meals. These produce isothiocyanates as they break down, and appear to directly suppress some pests. They may also act indirectly on the pests by favoring the growth of organisms antagonistic to the pathogens. [29]
13. Biomass: The total mass of all organisms in a given population or geographical area; usually expressed as total dry weight. Biological material derived from living, or recently living organisms. In the context of biomass for energy this is often used to mean plant based material, but biomass can equally apply to both animal and vegetable derived material. [57]
14. Bioplastics: Plastics in which all of its carbon atoms are derived from renewable feedstocks (a term defined below). They may or may not be biodegradable. (See also *biobased plastic*) [51]
15. Biopolymers: A polymeric substance (as a protein or polysaccharide) formed in a biological system. [14]
16. Carbon Black (dyeing agent): Any of various colloidal black substances consisting wholly or principally of carbon obtained usually as soot and used especially in tires and as pigments. [8]
17. Carbon pool: Amount of organic and inorganic carbon in a controlled volume of soil. [59]
18. Clean technology: A means of rendering goods or services that exhibit similar or better level of functionality, measurably superior environmental performance, at comparable long-run economic costs as that of those goods/services rendered by conventional technology. [12]
19. Compostability (of Plastics) Standard (ASTM D6400) : Standard specification for compostable plastics:
- For “...plastics that are designed to be composted in municipal and industrial aerobic composting facilities”
 - For “establish the requirements for labeling ...as “compostable in municipal and industrial composting facilities”
 - Degradable plastic: “...designed to undergo a significant change in its chemical structure under specific environmental conditions, resulting in a loss of some properties that may be measured by standard test methods”

- BD Plastic: “a degradable plastic in which the degradation results from the action of naturally occurring microorganisms such as bacteria, fungi, and algae.”
 - Requirement 1: Loss of 90% dry mass of plastic under composting during 12 weeks (ASTM D5338 [9] standardized biodegradability test)[14]
 - Requirement 2: (“inherent biodegradation”) 60% of C atoms converted to CO₂ in 180 days (compared to control) for single polymers (for blends, 60 or 90% conversion in 12 weeks, depending on the nature of the blend). [46]
20. Compostable plastic: A plastic that undergoes degradation by biological processes during composting to yield carbon dioxide, water, inorganic compounds, and biomass at a rate consistent with other known compostable materials, and leaves no visible, distinguishable, or toxic residue. [47]
21. Composting (agricultural sense): The process ‘to compost’ is the biological decomposition of organic materials by microorganisms under controlled, aerobic conditions to produce a relatively stable humus-like material called ‘compost’. For agricultural operations the common materials or feedstocks that are composted are livestock manures, livestock bedding, and various residual plant materials (straw, culls, on-farm processing wastes, etc.). Composting is much more than just allowing manure to pile up and decompose until ready for use—it is a science. The decomposition occurs in a well-managed process to obtain specific positive results—a valuable product—with a minimum of negative environmental impacts. [26]
22. Composting (materials sense): A managed process that controls the biological decomposition and transformation of biodegradable materials into a humus-like substance called compost: the aerobic mesophilic and thermophilic degradation of organic matter to make compost; the transformation of biologically decomposable material through a controlled process of bio-oxidation that proceed through mesophilic and thermophilic phases and results in the production of carbon dioxide, water, minerals, and stabilized organic matter. (compost or humus). [47]
23. Crop covers: Also called row covers. Flexible, transparent or semi-transparent materials used to cover and protect crops from cold, wind, and insect damage. Two main types of material commercially used are polyethylene (clear) and porous, floating, nonwoven polyester or polypropylene. Examples of trademark manufacturers include Reemay, DuPont, Kenbar, Polymax, Starfoam. [25]
24. Cover crop: A densely planted, natural or introduced crop grown primarily to improve and maintain soil structure, add organic matter, and prevent soil erosion. [45]
25. Cucurbit: A plant of the gourd family (*Cucurbitaceae*), which includes melon, pumpkin, squash, and cucumber. [13]
26. Degrade: Measurable conversion or mineralization of C to CO₂. Different than ‘*deterioration*’ – see definition below. [24]

27. Degradable plastic: Plastic designed to undergo a significant change in its chemical structure under specific environmental conditions, resulting in a loss of some properties that may be measured by standard test methods. [47]
28. Degradable polymeric material (or “plastic”): “designed to undergo a significant change in its chemical structure under specific environmental conditions resulting in a loss of some properties that may vary as measured by standard test methods appropriate to the polymeric material and the application in a period of time that determines its classification.” [35] Degradation: A deleterious change in the chemical structure, physical properties, or appearance of a plastic. [47]
29. Deterioration: Loss of physical or mechanical strength, as observed through physical strength testing, microscopic imaging, or sizable macroscopic alteration of morphology (e.g. rips, tears, and holes assessed visually). Different than ‘*degradation*’ – see definition above. [24]
30. Earthworm standardized test: Experimental quantification of number of earthworms per soil surface area. Earthworms are extracted by a solution of mustard. [59]
31. ‘End’ products: Final output of an activity, arrangement, or process. Articles, materials, and supplies delivered (or are to be delivered) under a contract. [9]
32. Enterprise Budget: A written goal statement for a crop or livestock production activity; listing the production goal, management activities, resource requirements, and economic returns. An enterprise budget contains the following elements or sections:
- production goal,
 - expected market price and gross receipts,
 - planned management activities with required resource inputs and costs, and
 - estimated net return and break-even price (BEP) for the goal production. [42]
33. Environmental burden: The total set of resources used, emissions and residues during the life cycle of a product or an item. Total impact on the environment of a construction product or project. [34]
34. Extrusion: A process by which a heated polymer is forced through an orifice to form a molten stream that is cooled to form a filament or fiber. A solution of the polymer can also be forced through the orifice into a solvent that causes the fiber to solidify. [10]
35. Extruder: An apparatus for extrusion. [10]
36. Fabric: A sheet structure made from fibers, filaments or yarns. [10]
37. Feedstock: Raw material to supply or fuel a machine or industrial process. [17]

38. Floating row covers: Floating row covers are made of spun-bonded polyester and spun-bonded polypropylene and are so lightweight that they "float" over most crops without support. (Crops with tender, exposed growing points, such as tomatoes and peppers, are exceptions; to prevent damage from wind abrasion, the cover should be supported with wire hoops.) The spun-bonded fabric is permeable to sunlight, water, and air, and provides a microclimate similar to the interior of a greenhouse. Plants are protected from drying winds by what amounts to a horizontal windbreak, and the covers give 2 to 8°F (1-4 °C) of frost protection. In addition to season extension, advantages include greater yields, higher-quality produce, and exclusion of insect pests. [3]
39. Fumigant: Vapor-active (volatile) pesticide or material used to kill disease-causing organisms, insects, nematodes, weeds, and other pests; a gaseous or readily volatilizable disinfectant or disinfectant used to destroy organisms by vapor action in an enclosed area or under plastic laid on the soil. Fumigants may be volatile liquids and solids as well as substances already gaseous. [45]
40. Genetically Modified Organisms (GMOs): An organism whose genome has been altered through genetic engineering to favor the expression of desired physiological traits or the output of desired biological products. [6]
41. Green chemistry: Green chemistry, also known as sustainable chemistry, is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, and use. [4]
42. Impact: The social, economic, civic, and/or environmental consequences of an educational program. Impacts tend to be longer-term and so may be equated with goals. Impacts may be positive, negative, and/or neutral and intended or unintended. [52]
43. Innovation: "An idea, practice, or object that is perceived as new by an individual or other unit of adoption. It matters little, so far as human behavior is concerned, whether or not an idea is 'objectively' new as measured by the lapse of time since its first use or discovery. The perceived newness of the idea for the individual determines his or her reaction to it. If an idea seems new to the individual, it is an innovation." [16]
44. Interdisciplinary Research: Any study or group of studies undertaken by scholars from two or more distinct scientific disciplines. The research is based upon a conceptual model that links or integrates theoretical frameworks from those disciplines, uses study design and methodology that is not limited to any one field, and requires the use of perspectives and skills of the involved disciplines throughout multiple phases of the research process. [21]

45. Landscape fabric: A textile material used to control weeds by inhibiting their exposure to sunlight. The fabric is normally placed around desirable plants, covering areas where other growth is unwanted. The fabric itself can be made from synthetic or organic materials, sometimes from recycled sources. [30]
46. Leaching (carbon leaching): Transfer of material (carbon) through action of water movement out of a controlled volume of soil. [31]
47. Life cycle assessment: The method/process for evaluating the effects that a product has on the environment over the entire period of its life from 'cradle to grave', thereby increasing resource use efficiency and decreasing liabilities. [43]
48. Lysimeter: An instrument to collect water percolating (leaching) through the soil. [31]
49. Lysimetry: The method associated with using a lysimeter. [31]
50. Meltblown: A nonwoven web forming process that extrudes and draws molten polymer resins with heated, high velocity air to form fine filaments. The filaments are cooled and collected as a web onto a moving screen. [10]
51. Mineralization: Microbial conversion of organic matter into inorganic substances, such as water and carbon dioxide. [19]
52. Mulch: (verb) Application of a covering (bulk, film or fabric) to the soil surface of a row of plants. (noun) Any product so applied. Common mulches include straw, sawdust and polyethylene film. Mulches are most commonly used to control weeds, but can also modify soil temperature and can reduce water loss due to evaporation from the soil surface. Film mulches are commonly used in solarization, fumigation and biofumigation. [35]
53. Nonwoven fabric: A fabric made directly from a web of fiber, without the yarn preparation necessary for weaving and knitting. In a nonwoven, the assembly of textile fibers is held together 1) by mechanical interlocking in a random web or mat; 2) by fusing of the fibers, as in the case of thermoplastic fibers; or 3) by bonding with acementing medium such as starch, casein, rubber latex, a cellulose derivative or synthetic resin. Initially, the fibers may be oriented in one direction or may be deposited in a random manner. This web or sheet is then bonded together by one of the methods described above. Fiber lengths can range from 0.25 inch to 6 inches for crimped fibers up to continuous filament in spunbonded fabrics. Nonwoven fabrics are currently used as weed mats, and row covers. [10]

54. Organic agriculture: According to the USDA National Organic Standards Board (NOSB), organic agriculture is defined as "an ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain, or enhance ecological harmony. [23]
55. Organic Materials Review Institute (OMRI): Provides third party, independent review of products intended for use in certified organic production, handling, and processing. Also provides technical support and training for professionals in the organic industry. A 501(c)3 nonprofit organization founded in 1997. When companies apply, OMRI reviews their products against the organic standards. Acceptable products are OMRI Listed® and appear on the *OMRI Products List*© or *OMRI Canada Products List*©. [36]
56. Organic standards: A federal program managed by USDA, the National Organic Program (NOP) has standards which producers must meet in order to be certified as organic. Standards include inputs and techniques that are allowable and not allowable. An overview of being certified organic includes: avoidance of prohibited synthetic chemical inputs (e.g. fertilizers, pesticides, antibiotics, food additives, etc), genetically modified organisms, irradiation, and the use of sewage sludge; use of farmland that has been free from chemicals for three or more years; keeping detailed written production and sales records (audit trail); maintaining strict physical separation of organic products from non- certified products; and undergoing periodic on-site inspections. [2]
57. Outcomes: Results or changes that occur from an educational effort. Outcomes may relate to changes in knowledge, awareness, skills, attitudes, opinions, aspirations, motivation, behavior, practice, decision-making, policies, social action, condition or status. Outcomes may be intended and unintended; positive and negative. Outcomes fall along a continuum from immediate (initial; short-term) to intermediate (medium-term) to final outcomes (long-term), often synonymous with impacts. [52]
58. Paper mulch: Products vary from 32-40-pound kraft paper, may be dyed black, unbleached, or undyed 100% recycled kraft paper. Papers may be treated with natural substances such as vegetable oil (soybean) and elemental sulfur. The product comes on rolls, generally 36 – 48 inches wide and up to 1500 feet long. Primarily used for weed control, soil moisture conservation, and soil erosion control. Tends to reduce soil temperature and is short lasting (3-4 months). Offers many of the advantages of plastic mulches, but does not require disposal as it is biodegradable and can be tilled into the soil after harvest. Trade name products include ‘Planters Paper’ and ‘Weed Guard’. [34]

59. Passive solar: Using sunlight for useful energy without use of active mechanical systems. Such technologies convert sunlight into usable heat (water, air, thermal mass), cause air-movement for ventilating, or store heat for future use, with little use of other energy sources. Passive solar systems have little to no operating costs, often have low maintenance costs, and emit no greenhouse gases in operation. [37]
60. PET: Polyethylene terephthalate (sometimes written poly(ethylene terephthalate)), is a thermoplastic polymer resin of the polyester family (derived from petroleum feedstock DGH) and is used in synthetic fibers; beverage, food and other liquid containers; thermoforming applications; and engineering resins often in combination with glass fiber. It is one of the most important raw materials used in man-made fibers. [39]
61. Plastic film: A thin sheet of plastic material, sometimes transparent, used to wrap or cover things. [41]
62. Plastic mulch: A thin plastic sheet usually 0.6 – 1.5 mm in thickness, available as 36 – 52 inches wide rolls, up to 6000 feet long and used to cover the soil in a bed or row primarily for weed control. Often used in conjunction with drip irrigation and crops grow through slits or holes in the plastic sheet. Impacts soil temperatures and conserves moisture from irrigation; available in various colors and weights. Disposal of the plastic mulch after use is an issue in most areas where it is used. [34]
63. Polyhydroxyalkanoate (PHA): Fatty acid biopolymers that are biosynthesized by microbial polyhydroxyalkanoate synthase enzymes. They are being investigated for use as biodegradable polyesters. [7]
64. Polylactic acid (PLA): A type of plastic, specifically a thermoplastic polyester. PLA is a more general classification that includes PLLA [poly(L-lactic acid)] , PDLA [poly(D-lactic acid)] , and PDLLA [poly(D,L-lactic acid) where polymers contain mixtures of D- and L- monomeric units). The differentiation is related to chiral carbon that occurs in lactic acid monomeric unit. (Its “building block” consists of OOC-CH(OH)CH₃.) Lactic acid produced by most organisms is primarily in the L-enantiomeric form. PLA is used in building models and prototypes of solid objects and components (such as in 3-D printing) and as an additive in manufacturing processes and applications. [38]
65. Polymer: A substance that has a molecular structure consisting chiefly or entirely of a large number of similar units bonded together, e.g., many synthetic organic materials used as plastics and resins. [40]
66. Powdery mildew: Fungus (or disease) that forms a superficial white coating on the surface of leaves, stems, fruits, buds, and flowers; generally refers to members of the *Erysiphales* or a type of disease caused by these fungi. Powdery mildew diseases are generally favored by high humidity rather than free moisture. [34]

67. Radiocarbon analysis (13C, 14C): Quantitative analysis of the amounts of 13C or 14C in sample. The amount of 13C or 14C is usually expressed in relation to the amount of 12C. [11]
68. Recycling: A resource recovery method involving the collection and treatment of waste products for use as raw material in the manufacture of same or similar product. [53]
69. Renewable materials: Renewable raw materials comprise the totality of plant, animal and microbial biomass, including biomass delivered through food chains, whose primary production is based on photosynthesis and which are provided for material and energy uses of all kinds outside food and feed. With material use, the biomass serves as raw material for the (industrial) production of all types of goods. [15]
70. Renewable resources: Resources capable of being continuously renewed or replaced through such processes as organic reproduction and cultivation such as those practiced in agriculture, animal husbandry, forestry and fisheries. [15]
71. Risk: The quantifiable uncertainty that could lead to changes in an individual's welfare such as losing money, potential harm to human health, and events that affect availability of resources, among others. In general agriculture risk typically is correlated with the chance of a negative outcome (e.g., financial loss or yield decrease) and the uncertainty in the decision making process due to incomplete information such as market prices. [20]
72. Risk Management: The evaluation of risk sources together with the identification of strategies to avoid or minimize their impact; the systematic application of management policies, procedures and practices to the tasks of identifying, analyzing, assessing treating and monitoring risk. [20] [22].
73. Row covers: See *cropcovers*. Flexible, translucent coverings made from polyester or polypropylene that are installed over single or multiple rows of horticultural crops in the field or high tunnel for the purpose of enhancing plant growth by warming the air around the plants, or to protect plants from insect pests (light weight row covers referred to as insect barrier). Floating row covers lie directly over the crops; several rows or a small field may be covered by one unit. [25]
74. *Sclerotinia sclerotiorum*: A fungus that causes white mold on plant stems and crowns on a wide variety of hosts, especially vegetables, and can survive in the soil for many years in overwintering structures called sclerotia. [34]
75. Smart materials: Materials that have one or more properties that can be significantly changed in a controlled fashion by external stimuli, such as stress, temperature, moisture, pH, electric or magnetic fields. [45]

76. Soil carbon: Sum of organic and inorganic carbon in soil. [59]
77. Soil Fumigation – The application of a fumigant, generally applied to soil under plastic, for the purpose of disinfecting the area. [modified from 45].
78. Soil organic carbon: Sum of all organic forms of carbon in the soil. [59]
79. Soil quality: The capacity of a soil to function. Soil quality can be assessed by measuring a set of soil properties to evaluate the soil's ability to perform basic functions (i.e., maintaining productivity, regulating and partitioning of water and solute flow, filtering and buffering against pollutants, and storing and cycling nutrients). [59]
80. Soil respiration: Respiration by organisms in the soil. Soil respiration is an indicator of biological activity (i.e., microbial and root), or soil life. This activity is as important to the soil ecosystem as healthy lungs are to us. [59]
81. Solarization: Elimination or suppression of plant pathogens, nematodes or weeds in the soil by solar heating. The soil is brought up to a moist, workable condition (typically about 70% of field capacity) and is worked to a fine texture. Clear film is laid tightly over the soil, and remains in place for several weeks to several months. The practice is most effective under hot, sunny conditions. [28]
82. Specialty crops: Fruits and vegetables, tree nuts, dried fruits, and horticulture and nursery crops including floriculture. [55]
83. Spunbond(ed): The filaments have been extruded, drawn and laid on a moving screen to form a web. The term is often interchanged with "spunlaid," but the industry conventionally adopted the spunbond or spunbonded term to denote a specific web forming process. This is to differentiate this web forming process from the other two forms of the spunlaid web forming, which are melt blown and flashspinning. [10]
84. Supply chain: A network of organizations involved in the supply and distribution of products, services, finances, and/or information from a source to a final user (e.g., consumer). Entire network of entities, directly or indirectly interlinked and interdependent in serving the same consumer or customer; including vendors that supply raw material, producers who convert the material into products, warehouses that store, distribution centers that deliver to the retailers, and retailers who bring the product to the ultimate user. [33] [50]

85. Sustainable agriculture: An integrated system of plant and animal production practices having a site-specific application that will over the long-term satisfy human food and fiber needs, enhance environmental quality and the natural resource base upon which the agriculture economy depends, make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls, sustain the economic viability of farm operations, and enhance the quality of life for farmers and society as a whole. [54]
86. Sustainable development: To meet the needs of the present without compromising the ability of future generations to meet their own needs. [58]
87. Sustainable material: Materials from renewable sources that can be produced at high volumes without adversely affecting the environment or critical ecologies. [46]
88. Synthetic material: (As per U.S. Organic Agriculture certification) “a substance that is formulated or manufactured by a chemical process or by a process that chemically changes a substance extracted from a naturally occurring plant, animal, or mineral sources, except that such term shall not apply to substances created by naturally occurring biological processes.” [2]
89. Transdisciplinary research: Research efforts conducted by investigators from different disciplines working jointly to create new conceptual, theoretical, methodological, and translational innovations that integrate and move beyond discipline-specific approaches to address a common problem. Transdisciplinary research also engages stakeholders in the conception, implementation, and evaluation of the research. [21]
90. USDA National Organic Program (NOP): Responsible for regulations and guidance on certification, production, handling, and labeling to ensure the integrity of USDA organic products in the U.S. and throughout the world. Organic is a labeling term that indicates that the food or other agricultural product has been produced through approved methods that integrate cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity. Synthetic fertilizers, sewage sludge, irradiation, and genetic engineering may not be used. [60]

REFERENCES

- [1] “Additive” Def. 1, *Oxford Dictionaries Online*, Oxford Dictionaries, n.d. Web. 14 Apr. [http:// http://www.oxforddictionaries.com](http://www.oxforddictionaries.com).
- [2] “Agriculture Marketing Service.” *U.S Department of Agriculture*. USDA. 4 February 2015. Web. 17 June 2014 <<http://www.ams.usda.gov/AMSV1.0/>>
- [3] Bachmann, J. *Season Extension Techniques for Market Gardeners*. NCAT, 2005. Print
- [4] “Basics of Green Chemistry”. *United States Environmental Protection Agency*. October 16, 2014. Web. 27 February 2015. <http://www2.epa.gov/green-chemistry/basics-green-chemistry#definition>
- [5] “Biodegradation”. *Wikipedia, the Free Encyclopedia*. 26 February 2015. Web. November 2010. <http://en.wikipedia.org/wiki/Biodegradation>>
- [6] “Biotechnology.” *U.S Department of Agriculture* . Economic Research Service. 2014. Web. 5 March 2015
- [7] “Biosynthesis of Polyhydroxyalkanoate Polymers from Industrial Wastewater”. *United States Environmental Protection Agency*. March 18, 2003. Web. 27 February 2015. http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractdetail/abstract/5955/report/0
- [8] “Black Carbon Basic Information”. *United States Environmental Protection Agency*. 30 March, 2012. Web. 27 February 2015. <<http://www.epa.gov/blackcarbon/basic.html>>
- [9] Business Dictionary “Final output of an activity, arrangement, or process.” December 2010. <http://www.businessdictionary.com/definition/end-product.html>
- [10] Butler, Ian. “INDA Nonwovens Glossary” *INDA Association of the Nonwoven Fabrics Industry Advancing Nonwovens Worldwide*. INDA. 1 of June. Web. 17 June 2014. <<http://inda.org/Glossary.pdf>>
- [11] Clark, I. and P. Fritz.. *Environmental Isotopes in Hydrogeology*. Lewis Publishers, 1997. Print.
- [12] Clift, Roland. “Clean technology-An introduction.” *J Chem. Tech. Biotechnol.*1995, 62. Print 321-326.
- [13] “Cucurbit.” 1. *Merriam-Webster Online*, Merriam-Webster, n.d. Web. 27 Feb. 2015. <<http://www.merriam-webster.com/dictionary/cucurbit>>
- [14] Daintith, John. “Biopolymer.” *A Dictionary of Chemistry (6 ed)*. Oxford University Press. Web. 5 March 2015.

- [15] “Environmental Terminology and Discovery Service” *European Environment Agency*. Web. June 2010
http://glossary.eea.europa.eu/terminology/concept_html?term=renewable%20resource>
- [16] Everett, E.M.. *Diffusion of Innovations, 5th edition*. New York: Free Press. 2003. Print.
- [17] “Feedstock” Def. 1. *Oxford Dictionaries Online*, Oxford Dictionaries, n.d. Web. 14 Apr. 2015 <http://www.oxforddictionaries.com>.
- [18] Gold, Mary. "Sustainable Agriculture: Definition and Terms." *United States Department of Agriculture National Agriculture Library*. 1 September, 1999. Web. 27 Feb. 2015.
 <<http://afsic.nal.usda.gov/sustainable-agriculture-definitions-and-terms-1#toc2>>.
- [19] Guggenberger, G. “Microorganisms and Soil Genesis”. F Buscot, A Varma (eds) *Microorganisms in soils:roles in Genesis and Functions* Berlin: Springer-Verlag, 2005. Print
- [20] Harwood, J., R. Heifner., K. Coble., J. Perry., and A. Somwaru. *Managing Risk in Farming: Concepts, Research, and Analysis*. Washington DC, U.S Department of Agriculture. 1999, ERS Economic Research Rep.774, March.
- [21] “Harvard Transdisciplinary Research in Energetics and Cancer Center” *Harvard T.H. Chan*. Web. 17 June 2014 <<http://www.hsph.harvard.edu/trec/about-us/definitions/>>
- [22] Hardaker, J.B., Huirne, R. B. M. and Anderson, J. R. *Coping with Risk in Agriculture*. CAB International. New York. 1997
- [23] Haumann, Barbra. “Organic Standards.” *Organic Trade Association*. Web. 17 June 2014.
<https://ota.com/learn-about-organic/organic-standards>
- [24] Hayes, Douglas G, Dharmalingam, Sathiskumar, Wadsworth, Larry C, Leonas, Karen K, Miles, Carol, Ingles, Debra A. “Biodegradable Agricultural Mulches Derived from Biopolymers.” *Degradable Polymers and Materials: Principles and Practice 2 Ed*. November 2012. Web. 6 March 2015
- [25] Hochmuth, GJ.,Hochmuth, RC., Kostewica, S. and Stall, W. “Row Covers for Commercial Vegetable Culture in Florida.” University of Florida IFA.2008. Web. November 2010. <<http://edis.ifas.ufl.edu/pdffiles/CV/CV20100.pdf>>
- [26] Hugh, Martin. “Agriculture Composting Basics”. *Fact Sheet*. Ontario Ministry of Agriculture Farm & Rural Affairs. 5 March. Web. 10 October.
 <<http://www.omafra.gov.on.ca/english/engineer/facts/05-023.htm>>
- [27] Kapanen, A., E.Schettini, G. Vox, and Itävaara. *Performance and Environmental Impact of Biodegradable Films in Agriculture: A Field Study on Protected Cultivation*. Journal of Polymers and the Environment 16, 2008. Print.
- [28] Katan, J. and J.E.DeVay, *Soil Solarization*. Boca Raton:CRC Press 199. Print

- [29] Kirkegaard, JA. Sarwar, M. Matthiessen, JN. “Assessing the biofumigation potential of cruciferae.” *Acta Hort*, 1998. Web. 459: 105–111.
- [30] “Landscape fabric” - *Wikipedia, the Free Encyclopedia*. Web. en.wikipedia.org/wiki/Landscape_fabric
- [31] Liu, Z., M. Flury, J. B. Harsh, J. B. Mathison, and C. Vogs. *Colloid mobilization in an undisturbed sediment core under semi-arid recharge rates*. 2013. *Water Resource. Res.* 49:4985–4996.
- [32] Maier, R.M., Pepper, I.L., and G.P. Gerba. (2009). *Environmental Microbiology*. Burlington: Elsevier Academic Press. 2009. Print.
- [33] Mentzer, J.T., W. DeWitt, J.S. Keebler, S. Min, N.W. Nix, C.D. Smith, and Z.G. Zacharia. 2001. “*Defining Supply Chain Management*.” *Journal of Business Logistics* 22(2): 1-25.
- [34] Miles C, Ponnaluru S, Galinato S, Inglis D, Marsh TA, Corbin A, Leonas KK, Walters T, Hayes DG, Jones R, Lee J, Wadsworth LC, Wszelaki AL, Belasco E, Moore-Kucera J, Wallace R, Brodhagen M. “Glossary of terms for biodegradable mulch for specialty crops produced under high tunnels. Web. 17 June 2014
<http://mtvernon.wsu.edu/hightunnels/Content/Glossary.pdf>
- [35] “Mulch”. *Wikipedia, the Free Encyclopedia*. 6 February 2015. Web. November 2010. <http://en.wikipedia.org/wiki/Mulch>
- [36] Organic Material Review Institute. Web. 2015. 20 April 2015 <https://www.omri.org/>
- [37] “Passive Solar building design”. *Wikipedia, the Free Encyclopedia*. Web. November 2010 <http://en.wikipedia.org/wiki/Passive_solar>
- [38] “Polyactic Acid”. *Wikipedia the Free Encyclopedia*. Web. October 2010 <http://en.wikipedia.org/wiki/Polylactic_acid>
- [39] “Polyethylene Terephthalate.” *Wikipedia, the Free Encyclopedia*. Web. October 2010. <http://en.wikipedia.org/wiki/Polyethylene_terephthalate>
- [40] “Polymer” Def. 1, In *Oxford Dictionaries Online*, Oxford Dictionaries Online, n.d. Web. 14, Apr. 2015. <http://www.oxforddictionaries.com>.
- [41] Princeton University, 2014. Web. December 2010. <<http://wordnetweb.princeton.edu/perl/webwn?s=plastic%20film>>
- [42] Rayburn, E. B. Estimating economic risk using Monte Carlo enterprise budgets. *Forge and Grazinglands* doi: 10.1094/FG-2009-0415-01-MG. 2009 Web.
- [43] “Risk Management Sustainable Technology.” *United States Environmental Protection Agency*. 5 August 2014. Web. 17 June 2014. <<http://www.epa.gov/nrmrl/std/lca/lca.html>>
- [44] Robison, L. J. and Barry, P. J. *Present Value Models and Investment Analysis*. 1996. Northport, AL. The Academic Page.

- [45] Shurtleff, M.C. and Averre, C.W. *A Glossary of Plant-Pathological Terms*. The American Phytopathological Society 1997. St. Paul, MN.
- [45] “Smart Material” *Wikipedia, the Free Encyclopedia*. Web. October 2010
http://en.wikipedia.org/wiki/Smart_materials
- [46] “Standard Specification for Labeling of Plastics Designed to be Aerobically Composted in Municipal or Industrial Facilities”. West Conshohocken: ASTM International, 2012. Print
- [47] “Standard Terminology Relating to Plastics”. ASTM D883. West Conshohocken: ASTM International, 2011. Print
- [48] “Standard Test Method for Determining Aerobic Biodegradation in Soil of Plastic Materials or Residual Plastic Materials After Composting”. ASTM D5988. West Conshohocken: ASTM International, 2012. Print
- [49] “Standard Test Method for Determining Aerobic Biodegradation of Plastic Materials Under Controlled Composting Conditions.” ASTM D5338. West Conshohocken: ASTM International, 2011. Print
- [50] “Supply chain.” *Business Dictionary Online*. Business Dictionary. Web. April 2015.
<http://www.businessdictionary.com/definition/supply-chain.html>
- [51] “Sustainable Plastics?” *Sustainable Biomaterials Collaborative*. Web. June 18 2014.
<http://www.sustainableplastics.org/>
- [52] Taylor-Powell, E and Henert, E. “Developing a logic model: Teaching and training guide” *UW Extension Cooperative Extension*. University of Wisconsin-Extension, Cooperate Extension, Program development and Evaluation. February 2008. Web. December 2010
<http://www.uwex.edu/ces/pdande/evaluation/pdf/lmguidecomplete.pdf>
- [53] “Technology Overview” *Conrad Industries*. 17 June 2014
http://www.conradind.com/to_conrad_system.asp
- [54] United State Code. 2011. Title 7, Agriculture. Section 3103. Government Printing Office. 5 March 2015.
- [55] “USDA Definition of Specialty Crops” Web. December 2010
http://www.nifa.usda.gov/funding/pdfs/definition_of_specialty_crops.pdf
- [56] “Welcome to Biopreferred Catalog”, *U.S. Dept. Agriculture* Web. 19 June 2014.
<http://www.biopreferred.gov/BioPreferred/faces/catalog/Catalog.xhtml>
- [57] “What is biomass?” *Welcome to the website of the BIOMASS Energy Centre*. Biomass Energy Centre, 2014. Web. 18 June 2014
<http://www.biomassenergycentre.org.uk>
- [58] World Commission on Environment and Development. 1987. *Report of the World Commission Environment and Development: Our Common Future*. UN Documents: Gathering a body of global Agreements. March 2015

- [59] U.S.Dept. Agriculture. 2001. Soil Quality Test Kit Guide. United States Department of Agriculture, Washington DC.
- [60] U.S. Dept. Agriculture. 2015. National Organic Program. 20 April 2015.
<<http://www.ams.usda.gov/AMSV1.0/ams.fetchTemplateData.do?template=TemplateA&navID=NationalOrganicProgram&leftNav=NationalOrganicProgram&page=NOPNationalOrganicProgramHome&acct=AMSPW>>