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VEGETATION ESTABLISHMENT EXPECTATIONS FOR EROSION CONTROL BLANKETS

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VEGETATION ESTABLISHMENT EXPECTATIONS FOR EROSION CONTROL BLANKETS

1. Purpose

a. This Public Works Technical Bulleting (PWTB) presents a discussion of the need for and utility of erosion control blankets (ECBs) to stabilize soil, prevent erosion, and maintain water quality on military lands. It also evaluates the rate of germination associated with an array of ECBs commonly used.

b. All PWTBs are available electronically at the National Institute of Building Sciences' Whole Building Design Guide webpage, which is accessible through this link:

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability

This PWTB applies to all civil and military US Army public works, natural resources, and environmental personnel responsible for erosion control implementation.

3. References

a. Clean Water Act of 1972 (33 U.S.C. §1251 et seq.) and amendments, including "National Pollution Discharge Elimination System (NPDES) Phase II. Stormwater Management Program," 1987.

b. Army Regulation (AR) 200-1, "Environmental Protection and Enhancement," 13 December 2007.

c. Executive Order (EO) 13514, “Federal Leadership in Environmental, Energy and Economic Performance,” 05 October 2009.

4. Discussion

a. The CWA and its amendments establish regulatory guidance to implement stormwater management practices for erosion and sediment discharges for receiving waters of the United States.

b. AR 200-1 implements federal, state, and local environmental laws and Dept. of Defense (DoD) policies for preserving, protecting, conserving, and restoring the quality of the environment; it is applicable specifically to the protection of natural resources such as soil and water.

c. EO 13514 directs federal agencies to pursue a clean energy economic policy. It requires the federal government to: increase energy efficiency; conserve and protect water resources through reuse and stormwater management; eliminate waste through recycling and pollution prevention; leverage agency acquisitions to foster markets for sustainable technologies and environmentally preferable materials, products, and services; and design, construct, maintain, and operate high-performance sustainable buildings in sustainable locations.

d. On construction and land rehabilitation projects, the presence of bare ground is a concern for the compliance and conservation efforts of contractors and land managers. Federal, state, and local regulatory requirements mandate that soil loss be minimized from those sites to preserve soil health and maintain clean waterways. Long-term ecological health of the land also requires that measures be taken to preserve soils in situ. In many areas, the best long-term solution is to establish vegetation. However, keeping soil in place while establishing a healthy stand of vegetation is frequently a challenge.

e. Many techniques and technologies are available to assist in soil stabilization on construction and rehabilitation sites. However, proper selection of technique/technology is necessary and is dependent on the size of the affected area, terrain slope, material cost, future precipitation timeframe, and whether the chosen product’s installation will be temporary or permanent. Mulches, polymers, and blankets are typical practices used to provide soil stabilization and counter the forces of wind and rain erosion. Over time, ECBs have increased in popularity due to their relatively low cost, ease of installation, and consistency in application. The manufacturers of these products have a range of different selections available depending on site, climate, and longevity requirements.

f. This PWTB provides an evaluation of germination and vegetation establishment from several readily available and commonly used products. These products were installed and monitored over a period of several weeks during summer 2012. Photographic methodologies recorded vegetative establishment and rates of growth. Resulting images were captured and analyzed by using vegetation analysis software. Information on soil erosion/deposition was not monitored during the period. At the end of the study period, the results from each product were statistically evaluated and compared against other products in the study to determine which product fared best. Six different ECB products were evaluated, along with a compost mixture and bare ground, for a total of eight treatments. The ECB treatment's rate of vegetative growth was measured every five days. An analysis of variance (ANOVA) test was performed for the treatments at every measurement period to determine if there were significant differences between products. Statistically significant differences did exist at varying times, but by the end of the study these differences disappeared. At the end of the study, the range of vegetative cover for the ECBs was 5.49%-14.98%. The product with the highest vegetation establishment rate was the recycled plastic turf reinforcement mat (TRM) at 14.98%. However, while the range did vary from product to product, the variation was not statistically significant. Thus from a vegetative establishment standpoint, one should install the product that is most cost effective and appropriate for site conditions. This is particularly important during final seeding and stabilization of a project, when the level of final vegetation coverage is critical. In certain circumstances, ecological considerations related to product longevity will be important. Also, product selection may be influenced by site maintenance requirements. This study indicates that a more resilient product would not necessarily yield higher final vegetation coverage and would waste financial resources.

g. East Central Illinois soil is some of the most productive and fertile in the world. Thus, the study site was an ideal environment to test under natural conditions how quickly vegetation can establish when using ECBs; the site's environment essentially sets an upper limit for temperate climates. Temperate climate military lands should expect similar high vegetation establishment percentages. Military lands located in more arid climates should have reduced expectations regarding drought-tolerant vegetation establishment, unless seeding occurs during the rainy season, or the project site is supplemented with additional water. During the dry season, the protective benefits of ECBs such as soil stabilization and reduction of the erosive from wind and rain are more critical factors in ECB selection. Further details regarding this study are explained in the PWTB's appendices.

h. Appendix A discusses the basic elements of erosion and sediment control (ESC).

i. Appendix B discusses the germination and selection of annual and perennial native grasses.

j. Appendix C contains a list of available erosion control product types and briefly describes products used in the demonstration and evaluation work done for this PWTB.

k. Appendix D briefly describes annual precipitation at select military installations and annual precipitation at the demonstration site.

l. Appendix E describes and presents results from a controlled hillside vegetation establishment study.

m. Appendix F details how the vegetation coverage was analyzed using the *ASSESS* photographic analysis software.

n. Appendix G contains a non-exhaustive list of erosion control product manufacturers and informational websites.

o. Appendix H lists references cited within this PWTB.

p. Appendix I lists acronyms and abbreviations used in this PWTB and gives their meaning.

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APPENDIX A: EROSION AND SEDIMENT CONTROL

Erosion is a naturally occurring process defined as the wearing away of the ground surface from the movement of wind, water, or ice. Sediments are a product of erosion; they are comprised of soils or other surficial materials transported by surface water (City of Minneapolis 1996). The main objective of erosion and sediment control (ESC) is to protect waterways from the destructive consequences of sedimentation. Sedimentation in the waterways leads to fish kills, clogged streams, reduced storage volume of reservoirs, and added filtration costs to municipal water supplies. Additionally, suspended soil particles block out light filtering through the water, thereby reducing in-stream photosynthesis and altering the ecology of affected waterways (NCDOT 2012). A secondary objective of ESC is to protect natural and engineered ground from processes that could result in stability problems on structures such as embankments, retaining walls, foundations, and piers, in or near waterways and other bodies of water.

By many accounts, the most environmentally dangerous period of time in land development is during the initial construction phase when land is cleared of vegetation and graded to create the desired surface for construction. The removal of natural vegetation and topsoil makes the exposed area particularly susceptible to erosion, causing transformation of existing drainage areas and disturbance of sensitive areas (USEPA 2012). The implementation of best management practices (BMPs) that prevent the loss of soil by stormwater runoff and/or wind erosion during the time the site is being disturbed is a major key to successful control of erosion and sedimentation (USGBC 2003).

Erosion control measures must be in place before an activity begins, and they must remain in place and functional until the site is permanently stabilized (MDEP 2011). Federal and state regulations require those who perform land-altering activities to adhere to the effluent limitations prescribed by the law. Discharge constraints are best achieved by acquiring required permits and by monitoring the area under construction. Sections 401, 404, and 303d of the Clean Water Act (CWA) establish the framework for the discharge of sediment from a construction site.

The use of ESC products such as rolled erosion control products (RECPs) (i.e., erosion control blankets [ECBs]) can be an effective way to meet federal and state water quality levels.

Table A-1 provides a partial list of BMPs for controlling erosion and sediment at construction sites.

Table A-1. BMPs for controlling erosion and sediment (USGBC 2003).

BMP	Description
	Stabilization
Temporary seeding	Plant fast-growing grasses to temporarily stabilize soils.
Permanent seeding	Plant grass, trees, and shrubs to permanently stabilize soils.
Mulching	Place hay, grass, woodchips, straw, shredded tires, or gravel on the soil surface to cover and hold soils.
	Structural Control
Earth dike	Construct a mound of stabilized soil to divert surface runoff volumes from disturbed areas or into sediment basins or sediment traps.
Silt fence	Construct posts with a filter fabric media to remove sediment from stormwater volumes flowing through the fence.
Sediment trap	Excavate a pond area or construct earthen embankments to allow for settling of sediment from stormwater volumes.
Sediment basin	Construct a pond with a controlled water release structure to allow for settling of sediment from stormwater volumes.

APPENDIX B: GERMINATION AND GRASS SELECTION

Germination of grasses is essential for successful reduction of erosion (Gyasi-Agyei 2004). Established vegetation helps to reduce the impact of rainfall on the soil and to reduce runoff by encouraging infiltration (Fox et al. 2011). For long-term soil erosion control, a mix of seeds containing annual and perennial grass species is ideal. Annual grasses establish quickly to bind the top soil and deter establishment of weedy species. Although their fast growth and abundance makes weedy species useful for erosion control, they significantly alter plant composition by outcompeting desired vegetation for water and nutrients (Benik et al. 2000). Perennial grasses establish more slowly, but develop deeper roots (which provide longer-term erosion control) than annual species which die off at the end of the growing season (Fox et al. 2011).

Climate, soil type, and durability of the vegetation determine the type of seed to be planted (Fox 2011). The demonstration and validation study discussed in this PWTB planted seed types in the native grass mix that "possess qualities favorable for reducing the availability of specific soil contaminants, either through degradation or stabilization." Soil contaminants are often a problem in areas such as military installations that need land rehabilitation (USACE 2007). Some native grasses also tend to be limited in height, which results in lower maintenance requirements, and this is a desirable quality on steep slopes (Benik et al. 2000).

While native grasses have multiple benefits, the reliable establishment rate of tall fescue often makes it a preferred species for planting. Tall fescue grows best in moist environments; it has high drought tolerance and will survive during dry periods in a dormant state; it is adapted to a wide range of soils, but does best in clay soils high with organic matter content (Duble 2008). When seeding tall fescue turf, a planting rate of 19–43 g/m^2 or more is often recommended. This planting rate range, which is much higher than that recommended for pasture plantings, results in approximately 1–2 $seeds/cm^2$ (Samples et al. 2010). In favorable conditions, the tall fescue seed will germinate in less than 11 days (Waltz and Landry 2005).

The use of cover in cold as well as warm weather has proven successful in aiding germination of some types of grass. Covers such as polypropylene/plastic covers, and natural materials such as jute, coconut fiber, straw and thermal blankets have been used with bermudagrass, buffalograss, zoysiagrass etc. (Patton et al 2010).

This work investigated the germination of both native grasses and fescues; a fescue grass mix was chosen for use in the field investigation because of its reliability and consistency in the establishment of vegetation. Native grass mixes are typically the preferred mixes used on military lands. However, their slow and inconsistent rate of establishment did not make them ideal for the study. In instances where native grass mixes are used, the mixes generally contain annual seeds to bridge the long period before native vegetation begins to establish. For the study location, grass selection was based on information derived from the Illinois Department of Transportation (IDOT) seeding guidelines (IDOT 2002).

APPENDIX C:
EROSION CONTROL PRODUCTS

Introduction

Federal legislation (CWA and US Energy Independence and Security Act of 2007 [EISA], Section 438) and a US Department of Defense (DoD) policy (DoD Implementation of Stormwater Requirements under Section 438 of the EISA) direct the Army to manage stormwater differently from how it has been managed in the past. Additionally, Executive Order (EO) 13514 orders all new land development to reduce stormwater runoff sediments (non-point source pollutants) to a predevelopment state (White House 2009). DoD is operating to meet that mandate; however, that mandate presents some unique challenges due to the nature of the military's scope of activities, scale of operations, and distribution of lands.

Part of the solution for meeting these requirements is to maintain well-established vegetation while implementing BMPs that ensure permanent erosion control. One of the most common BMPs used to control soil loss while seed establishes on bare soils is to use RECPs (in this case, ECBs) to reduce runoff and to provide protection and anchorage for young vegetation.

The current assumption is that ECB selection matters little with regards to vegetation germination (i.e., “one ECB is as good as another”). Published literature does not address this issue, and observational data suggest that not all available ECBs are equally capable at promoting vegetation growth. It is in DoD land managers’ best interest to select products most appropriate for their application to promote rapid vegetation establishment in a cost-effective manner.

This project investigated vegetation establishment rates of several different ECBs (natural and synthetic) while using a single (constant) seed mixture to determine if the rate of germination under various ECBs varies significantly under different treatments. The overall goal of this project is to provide ECB selection guidance that will enable land managers to achieve optimum vegetation establishment, which will help installations to meet environmental requirements. Small-scale, close-to-the-source controls are necessary to meet the environmental standards for stormwater management under the auspices of National Pollutant Discharge Elimination System (NPDES) and Phase II of the CWA at sites of significant land disturbance. This work evaluated the effectiveness of natural and synthetic ECBs and measured the germination rates that each of the ECBs yielded during the demonstration period.

The majority of ECBs are manufactured from straw or wood fibers. Wood fiber material is designed with barbs and curls that cut into the soil and secure the blanket to the soil (Aird 2008). Since they are biodegradable, most ECBs are engineered for "areas where natural, unreinforced vegetation alone will provide long-term soil stabilization." Available ECBs differ broadly in their blanket strength, durability, and functional longevity (Allen 1996). Also, newer products have incorporated synthetic fibers to increase longevity and broaden product application to areas where natural vegetation alone would not be sufficient to provide long-term stabilization.

Compost has been used in conjunction with ECBs for erosion control. Compost releases nutrients and is ideal for use with soil that has specific carbon to nitrogen ratio needs. Compost also insulates the topsoil and reduces water evaporation, providing a more suitable environment for germination and root growth (Faucette et al. 2006).

The following paragraphs detail specific ECB products used in this demonstration and evaluation.

Products Used

Light Double-Net Excelsior ECB. Derived from either Aspen or Pine wood, this ECB has interlocking fibers that are meant to decrease water velocity, thereby allowing moisture to slowly make contact with the soil (Figure C-1). The lower water velocity improves the growing environment for seeds. This ECB has a top and bottom net, often made of biodegradable materials. While comprised of the same materials as the standard double-net excelsior ECB, it is less dense and thus easier to handle. This ECB is applicable on slopes with gradients less than 1.5H:1V and can withstand relatively high shear stress rates.

Figure C-1. Light double-net excelsior ECB.

Double-Net Excelsior ECB. As a double-netted product (Figure C-2), this ECB is intended to provide protection for grass seed and topsoil for a longer time, generally up to 36 months. The double-net ECB is designed for application to slopes with gradients less than 1H:1V and can withstand relatively high shear stress rates.

Figure C-2. Double-net excelsior ECB.

Net-Free Excelsior ECB. This ECB is generally manufactured to be 100% biodegradable. A main benefit of its biodegradability is that the product is suitable for areas of high activity or mowing, and it reduces the risk of wildlife becoming trapped. This ECB is composed of interlocking aspen, pine, or coconut wood fibers stitched together with biodegradable thread (Figure C-3). Products of this type are designed for lower slope situations; they can effectively withstand an incline of no more than 3H:1V and subsequently, lower sheer stress rates.

Figure C-3. Net-free excelsior ECB.

Excelsior TRM. This heavy-duty biocomposite TRM (Figure C-4) can remain effective for longer periods, up to 36 months. While this ECB’s composite wood fibers will degrade naturally, the dual layers of plastic netting will remain in place. Products of this nature are intended for steeper slopes; they can withstand gradients of 0.5H:1V. When installed properly, the product can also remain in place against sheer stresses of 480 Pa.

Figure C-4. Excelsior TRM.

Recycled Plastic TRM. This product is comprised of 100% recycled post-consumer plastic and is intended to be used as a long-term erosion protection treatment (Figure C-5). Similar to its wood fiber-comprised cousins, its interlocking fibers conform to the terrain and work to lower the velocity of water as it travels through the blanket. Its ability to withstand slopes and sheer stress is similar to that of the Excelsior TRM.

Figure C-5. Recycled plastic TRM.

Double-Net Straw ECB. This ECB (Figure C-6) is generally manufactured to be 100% biodegradable, although a variety of non-biodegradable and biodegradable stitching options are commonly available. The straws will biodegrade in less than 1 year, depending on the environment. Due to its composition, this ECB is lightweight and easy to handle. It has a relatively moderate shear stress rating and is designed to generally withstand slopes with gradients of 2H:1V or less.

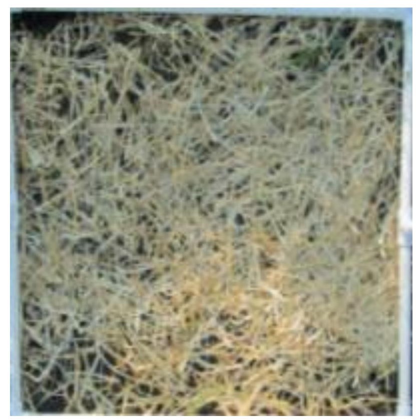

Figure C-6. Double-net straw ECB.

Compost. Compost (Figure C-7) can greatly reduce erosion when compared to bare soil, and it contributes to a higher vegetative biomass than mulch treatments. Using compost for erosion control is also a sustainable method of dealing with waste materials. Compost on topsoil insulates the seeds, leading to higher vegetation establishment (Risse 2003). Compost used in this study was acquired from the local landscape recycling center. The screened garden compost is comprised primarily of organic plant waste and is nutrient rich.

Figure C-7. Compost treatment.

Bare Ground. Bare topsoil serves as a control treatment. Each treatment was then assigned a number to ease reporting results (Table C-1).

Table C-1. Treatment description and number.

Treatment Description	Treatment No.
Bare ground	1
Recycled plastic TRM	2
Excelsior TRM	3
Net-free excelsior ECB	4
Double-net excelsior ECB	5
Double-net straw ECB	6
Compost	7
Light double-net excelsior ECB	8

APPENDIX D: IDENTIFICATION OF OPTIMAL VEGETATION ESTABLISHMENT PERIODS ON DOD INSTALLATIONS

Figures D-2 and D-3 show average monthly precipitation at a select range of US military installations and at the study site. Installations were selected to provide a representative cross-section of different regions across the coterminous United States. These locations' precipitation data were obtained from the National Oceanic and Atmospheric Administration (NOAA).[1] This information provides a basis for comparison between precipitation at the demonstration site and precipitation at the installations, and may be used to identify optimal periods for establishing vegetation at the installations.

Additionally, climate classifications are presented in Table D-1 to allow for further comparisons between the selected installations and the study site. Aridity index values were derived by using the methodology used to quantify precipitation availability over atmospheric water demand (UNEP 1997). Also, a map showing various climate zones and corresponding US military installations may be used as a guide in vegetation selection (Figure D-1).

Many regions across the continental United States experience a rainy period at least once during a calendar year. Grasses, especially tall fescues, will germinate and thrive if seeded at the start of a rainy period. Timing is critical, however, particularly in more arid regions where the seeding timeframe is short. It is recommended to plant grass seed at the start of the first calendar year's rainy period. The earlier start allows a second seeding attempt if the first seeding attempt does not generate the desired results.

[1] www.noaa.gov

Table D-1. Aridity Values for select military installations.

Location	Aridity Index Value	Climate Class	Coordinates (Lat./Long.)
Fort Benning, GA	0.824	Humid	32°21′58″N 84°58′09″W
Fort Bliss, TX	0.136	Arid	31°48′07″N 106°25′29″W
Fort Bragg, NC	0.935	Humid	35°8′21″N 78°59′57″W
Fort Campbell, KY	1.006	Humid	36°39′N 87°28′W
Fort Carson, CO	0.337	Semi-Arid	38°33′20″N 104°50′33″W
Fort Drum, NY	1.169	Humid	44°2′17″N 75°45′29″W
Fort Hood, TX	0.562	Dry Sub-Humid	31°08′N 97°47′W
Fort Irwin, CA	0.076	Arid	35°14′47″N 116°40′55″W
Fort Polk, LA	1.025	Humid	31°04′21″N 93°04′50″W
Fort Riley, KS	0.698	Humid	39°06′N 96°49′W
Fort Stewart, GA	0.870	Humid	31°52′48″N 81°36′27″W
Yakima Trng Ctr, WA	0.293	Semi-Arid	46°45′40″N 120°11′29″W
Study Site	0.913	Humid	40°6′37.94″N 88°13′42.28″W

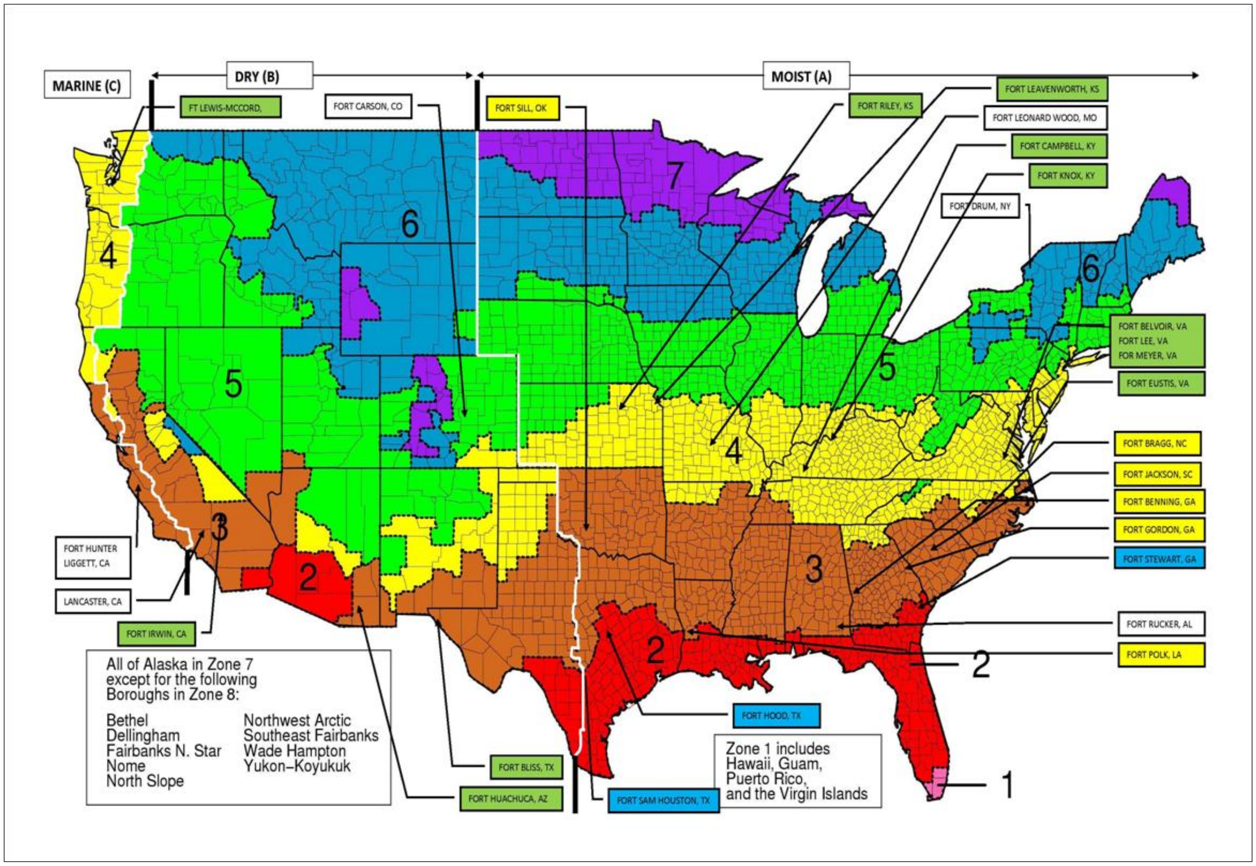

Figure D-1. US Military installation climate zones (www.naturegrounds.org).

An examination of average monthly precipitation values for the installations in Figure D-2 and Figure D-3 illustrates that the study site receives frequent precipitation. Yakima Training Center, Fort Carson, Fort Irwin, and Fort Bliss are located in arid regions of the United States where vegetation establishment is more difficult to achieve than at temperate/humid climate installations (Table D-1). Because arid installations receive such infrequent precipitation, it is critical that vegetation establishment efforts be timed appropriately with wet periods and/or supplemented with watering strategies.

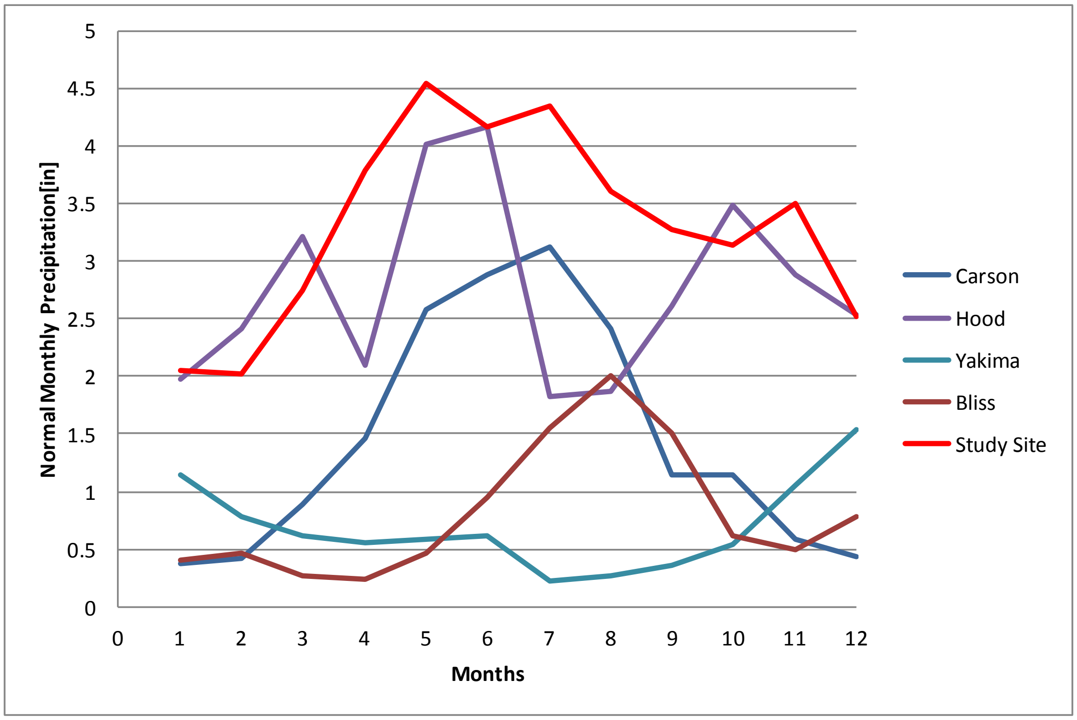

Figure D-2. Comparison of monthly average precipitation at four select military installations and the study site.

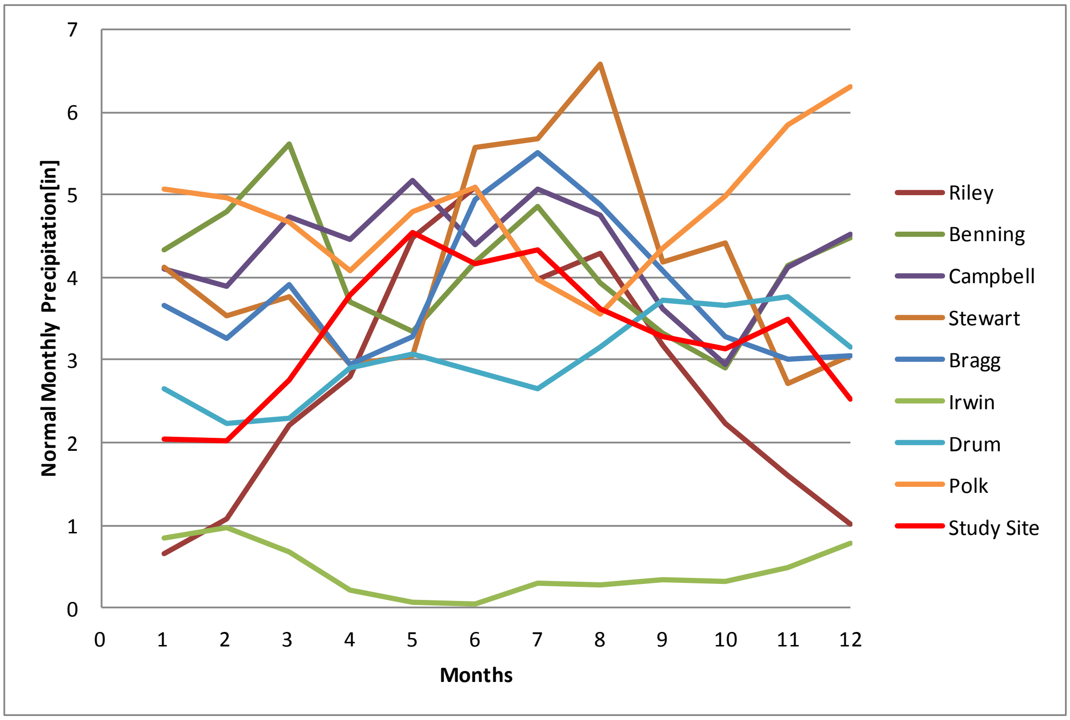

Figure D-3. Comparison of monthly average precipitation at eight additional military installations and the study site.

APPENDIX E:
VEGETATION ESTABLISHMENT

Experimental Procedures

Description and Preparation

The research site was located on the east-facing, north-south oriented back slope of a berm at the University of Illinois (UI) Agricultural and Biological Engineering Department's research farm south of the UI campus at Urbana, IL. The berm is approximately 12 ft high with a front slope gradient of 3H:1V and a back slope gradient of 2H:1V.

Along with plots configured to use compost and bare ground, a total of six different ECB products were demonstrated: recycled plastic TRM, excelsior TRM, net-free excelsior ECB, double-net excelsior ECB, double-net straw ECB, and light double-net excelsior ECB. A randomized block experimental design was selected to conduct the demonstrations and evaluations. The eight treatments were replicated four times along the 2H:1V slope for a total of 32 plots of 0.5 m^2.

The plots were initially mowed and sprayed with glyphosate herbicide to remove any existing vegetation. The plots were then monitored for 50 days to let herbicide kill the existing vegetation. The plots were then scraped by using a backhoe to remove any dead vegetation and debris. The plots were then hand raked to break up dirt clods and to provide a smooth surface for seed and ECB installation (Figure E-1).

Figure E-1. Seeded and blanketed vegetation establishment plots.

A common seed, Kentucky 31 Tall Fescue, was used in each plot at a broadcast seeding rate of 100 g per m^2. This seed was chosen due its ease of application and establishment.

After installation of the ECBs, one watermark sensor was placed in each treatment to measure soil moisture. The sensors were set to take readings every 5 min. Average soil temperature was set to 78°F.

Data Collection and Observations

Each plot was monitored for vegetation establishment twice weekly. Digital photographs were taken for later analysis at approximately the same time of day to minimize differences in lighting. A 0.5 m x 0.5 m quadrat with camera stand was used (Figure E-2) to ensure image continuity throughout the study. The photos were analyzed for percent vegetation for each plot site using *ASSESS* photo-analysis software (Lamari 2002), as described in detail in Appendix F.

The recorded moisture ranged from 4 to 32 centibars during the 13-day pre-germination period. At Day 14, significant germination was visible, and fescue vegetation was able to be photographed. Although the grass initially appeared sparse, it was clear that the fescue was growing and had not been washed away by the previous week’s rainstorms. Upon the confirmation of vegetation growth, the watermark sensors were activated and began recording soil moisture at 5-minute intervals. The recorded soil moisture content during the germination period is shown (by treatment) in Figure E-3.

Results

The vegetation photos were analyzed 26 days after installation of the ECB treatments. The data were generated from the *ASSESS* photo-analysis program to determine vegetation percentage. The average was calculated by equally weighting the replications of each individual treatment by 0.25 and summing the values for each column. The total growth coverage value is the total percentage of vegetation recorded on the last day of the study, Day 26.

Figures E-4 through E-12 and Tables E-1 through E-10 show or tabulate the results for individual treatment types and average results from all types.

Figure E-2. Camera stand used to photograph plots.

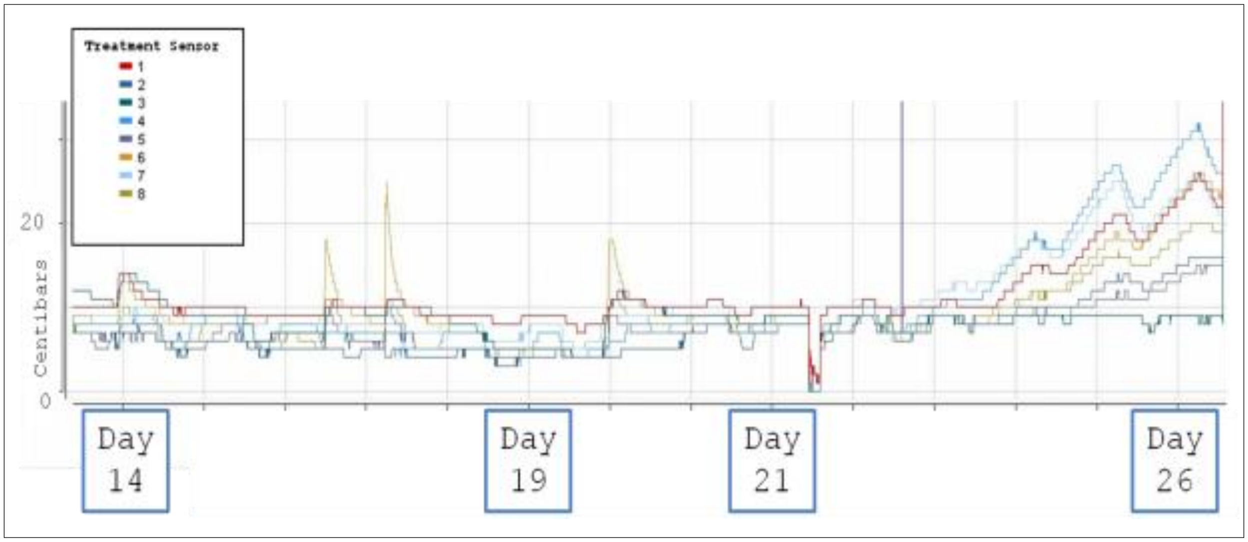

Figure E-3. Recorded soil moisture content by treatment over germination period.

Table E-1. Treatment No. 1 (bare ground).

Replication	Day 14 (%)	Day 19 (%)	Day 21 (%)	Day 26 (%)	Total Growth Coverage (%)
1	0.03	2.78	5.06	7.99	7.99
2	0.60	6.61	6.56	18.48	18.48
3	0.57	1.26	6.08	9.36	9.36
4	0.29	3.6	8.48	13.77	13.77
Average	0.37	3.58	6.55	12.40	12.40

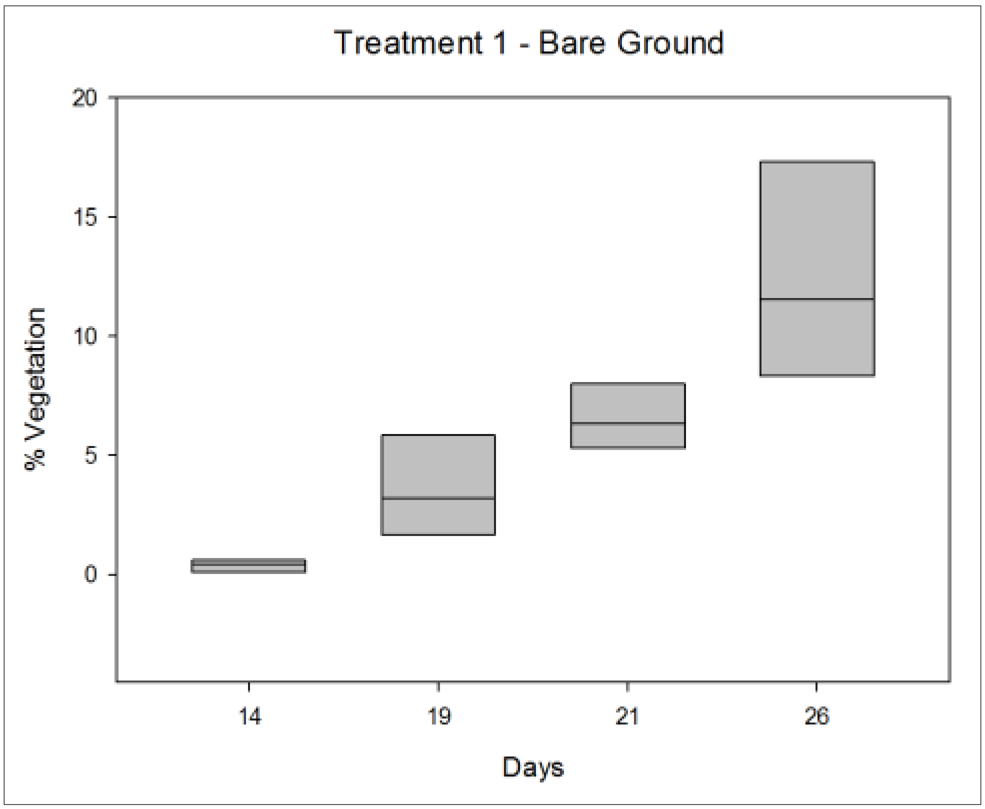

Figure E-4. Bare ground box plot.

Table E-2. Treatment No. 2 (recycled plastic TRM).

Replication	Day 14 (%)	Day 19 (%)	Day 21 (%)	Day 26 (%)	Total Growth Coverage (%)
1	1.05	7.32	8.50	12.21	12.21
2	3.47	4.60	6.85	10.19	10.19
3	2.89	2.02	19.79	23.82	23.82
4	0.81	6.71	13.94	13.70	13.70
Average	2.06	5.16	12.27	14.98	14.98

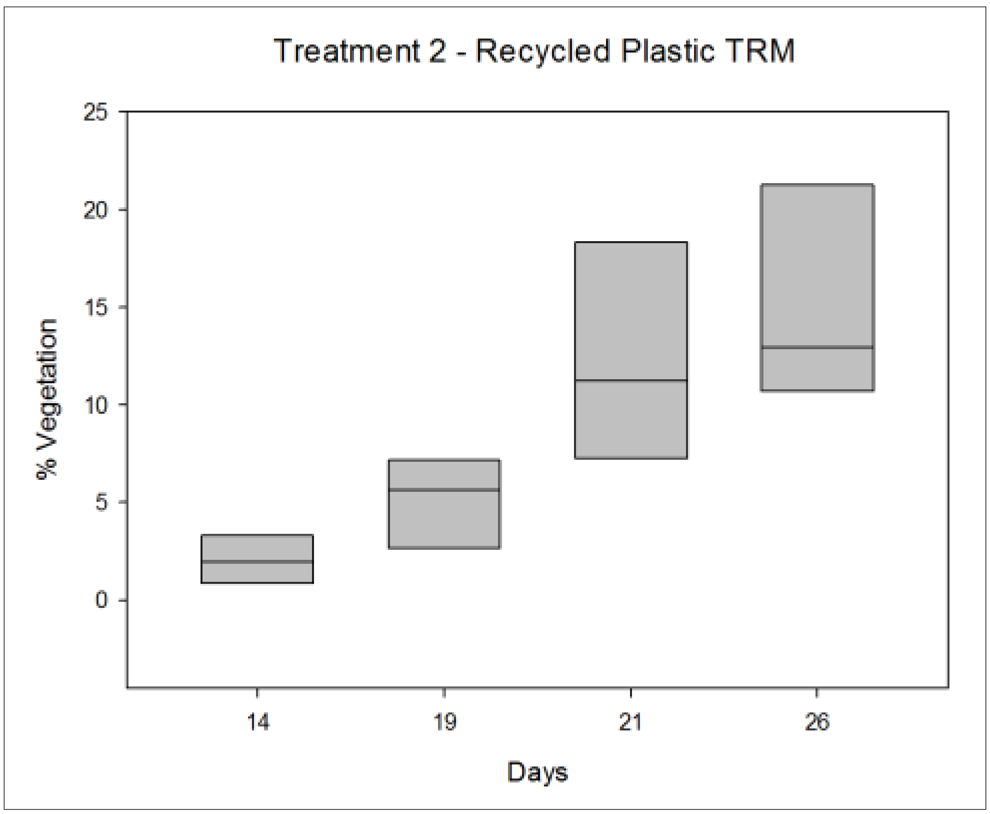

Figure E-5. Recycled plastic TRM box plot.

Table E-3. Treatment No. 3 (excelsior TRM).

Replication	Day 14 (%)	Day 19 (%)	Day 21 (%)	Day 26 (%)	Total Growth Coverage (%)
1	1.96	4.75	3.20	7.30	7.30
2	0.58	4.74	4.58	9.27	9.27
3	1.34	7.36	10.13	8.77	8.77
4	0.83	2.52	6.98	11.42	11.42
Average	1.18	4.84	6.22	9.19	9.19

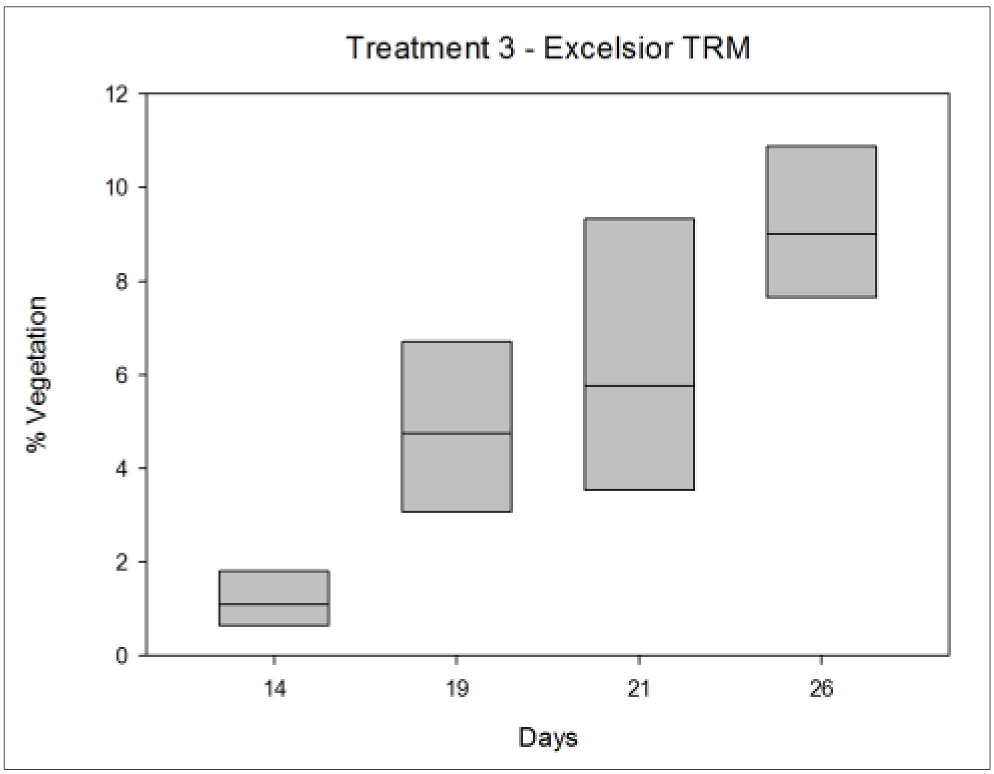

Figure E-6. Excelsior TRM box plot.

Table E-4. Treatment No. 4 (net-free excelsior ECB).

Replication	Day 14 (%)	Day 19 (%)	Day 21 (%)	Day 26 (%)	Total Growth Coverage (%)
1	0.00	1.64	2.42	5.24	5.24
2	1.91	2.92	5.02	7.12	7.12
3	0.00	1.76	4.26	3.84	3.84
4	0.00	0.50	6.56	8.32	8.32
Average	0.48	1.71	4.57	6.13	6.13

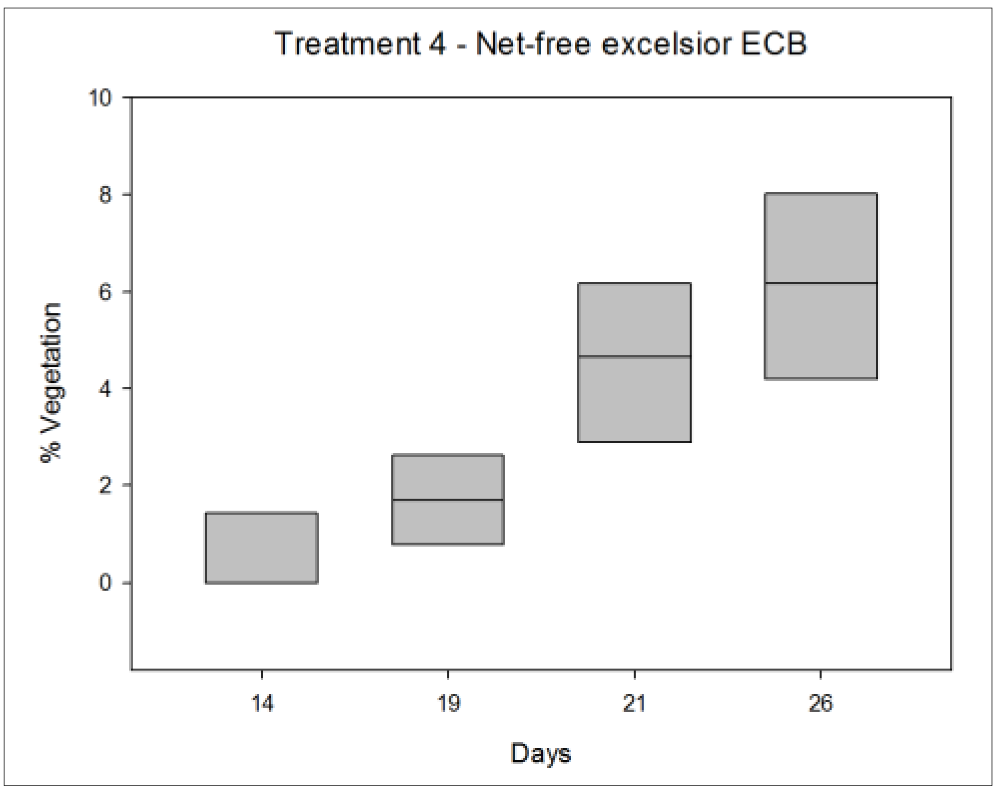

Figure E-7. Net-free excelsior ECB box plot.

Table E-5. Treatment No. 5 (double-net excelsior ECB).

Replication	Day 14 (%)	Day 19 (%)	Day 21 (%)	Day 26 (%)	Total Growth Coverage (%)
1	1.98	5.51	4.24	5.19	5.19
2	0.00	9.67	5.59	5.64	5.64
3	0.15	5.43	5.14	5.76	5.76
4	0.00	5.33	7.91	5.36	5.36
Average	0.53	6.49	5.72	5.49	5.49

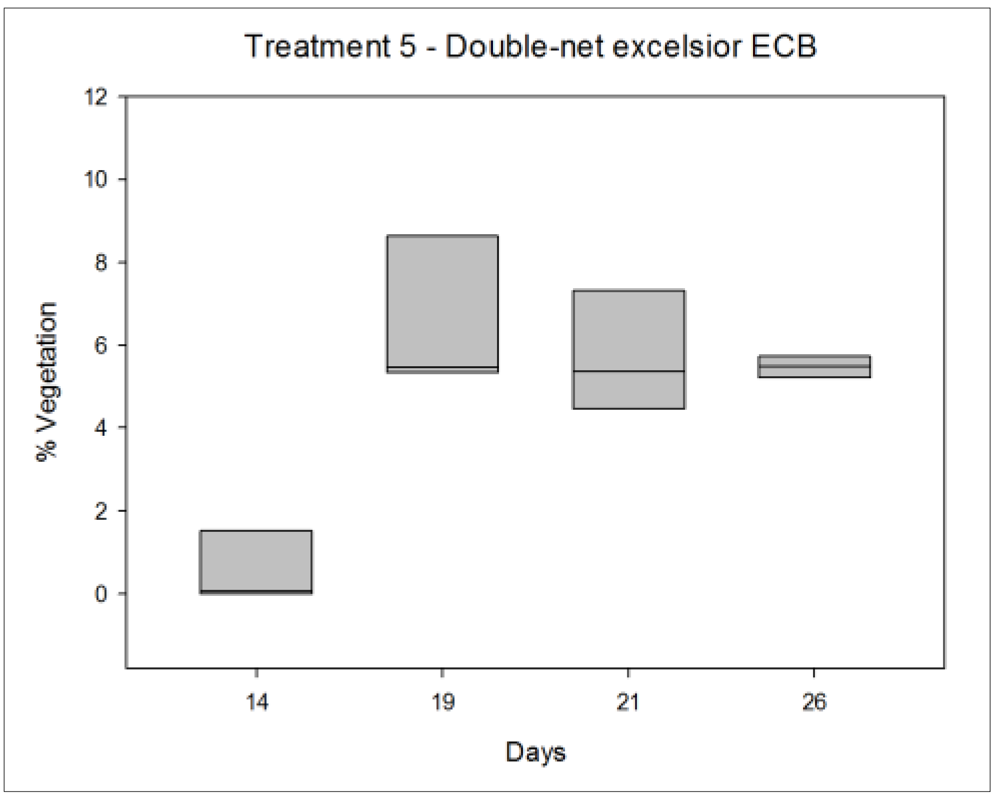

Figure E-8. Double-net excelsior ECB box plot.

Table E-6. Treatment No. 6 (double-net straw ECB).

Replication	Day 14 (%)	Day 19 (%)	Day 21 (%)	Day 26 (%)	Total Growth Coverage (%)
1	0.00	2.71	2.90	5.32	5.32
2	0.00	2.47	3.03	5.72	5.72
3	0.00	2.68	4.64	7.38	7.38
4	0.00	1.99	4.67	8.30	8.3
Average	0.00	2.46	3.81	6.68	6.68

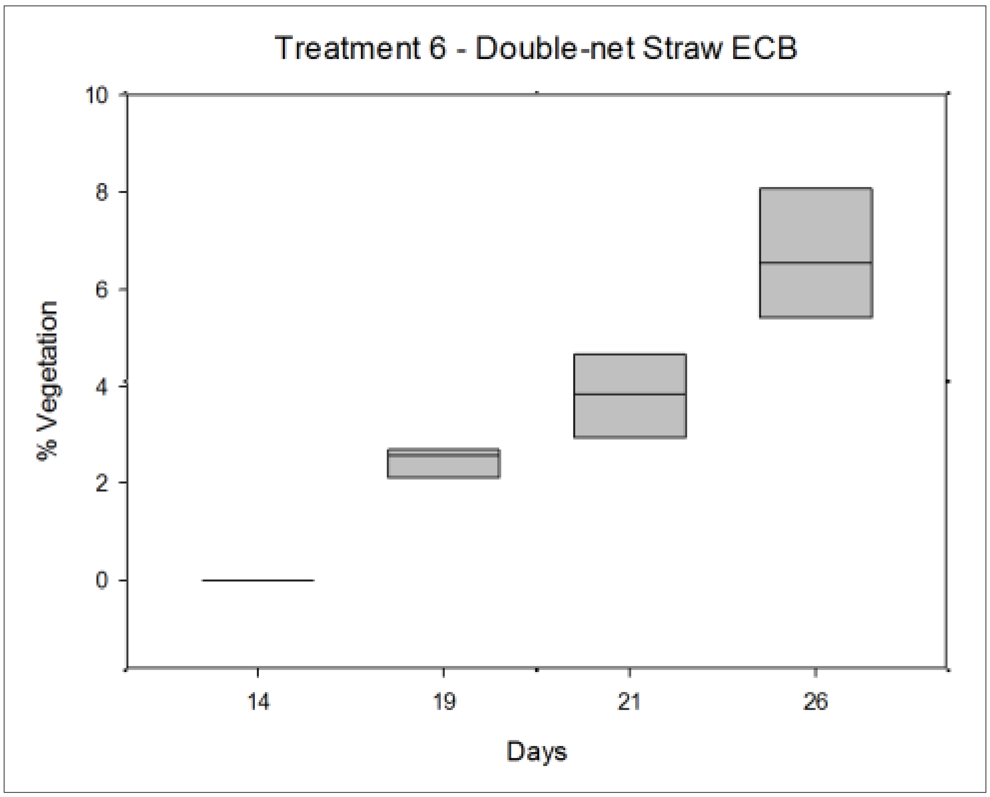

Figure E-9. Double-net straw ECB box plot.

Table E-7. Treatment No. 7 (compost).

Replication	**Day 14 (%)**	**Day 19 (%)**	**Day 21 (%)**	**Day 26 (%)**	**Total Growth Coverage (%)**
1	0.00	6.46	15.46	19.27	19.27
2	0.19	4.73	12.60	17.76	17.76
3	0.06	4.13	12.91	17.01	17.01
4	0.29	4.45	12.85	18.41	18.41
Average	0.14	4.94	13.46	18.11	18.11

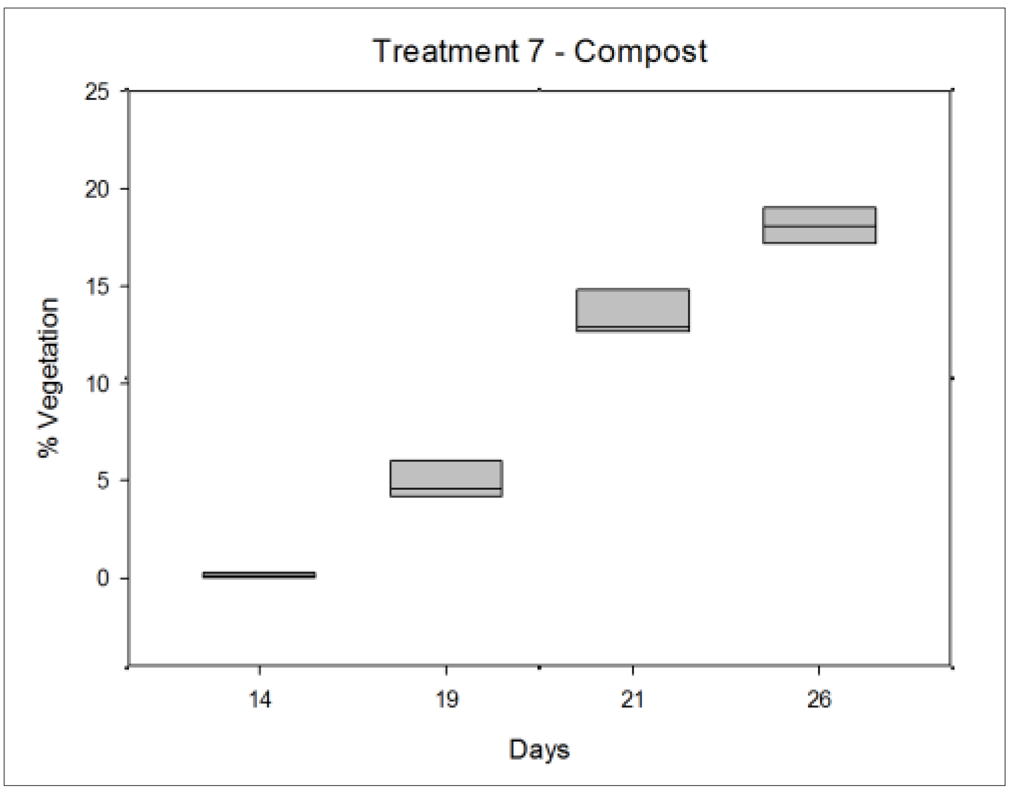

Figure E-10. Compost box plot.

Table E-8. Treatment No. 8 (light double-net excelsior ECB).

Replication	Day 14 (%)	Day 19 (%)	Day 21 (%)	Day 26 (%)	Total Growth Coverage (%)
1	3.82	10.86	11.37	11.78	11.78
2	0.00	12.19	5.79	12.14	12.14
3	0.00	4.68	6.64	9.05	9.05
4	0.22	9.11	4.67	8.19	8.19
Average	1.01	9.21	7.12	10.29	10.29

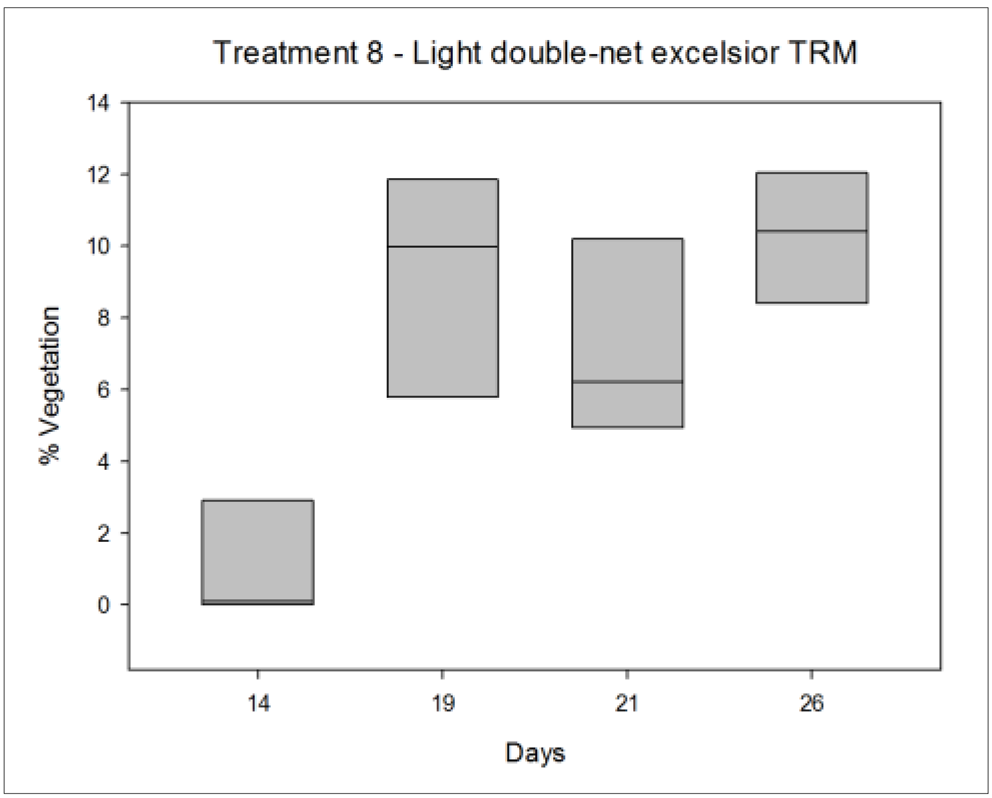

Figure E-11. Light double-net excelsior ECB box plot.

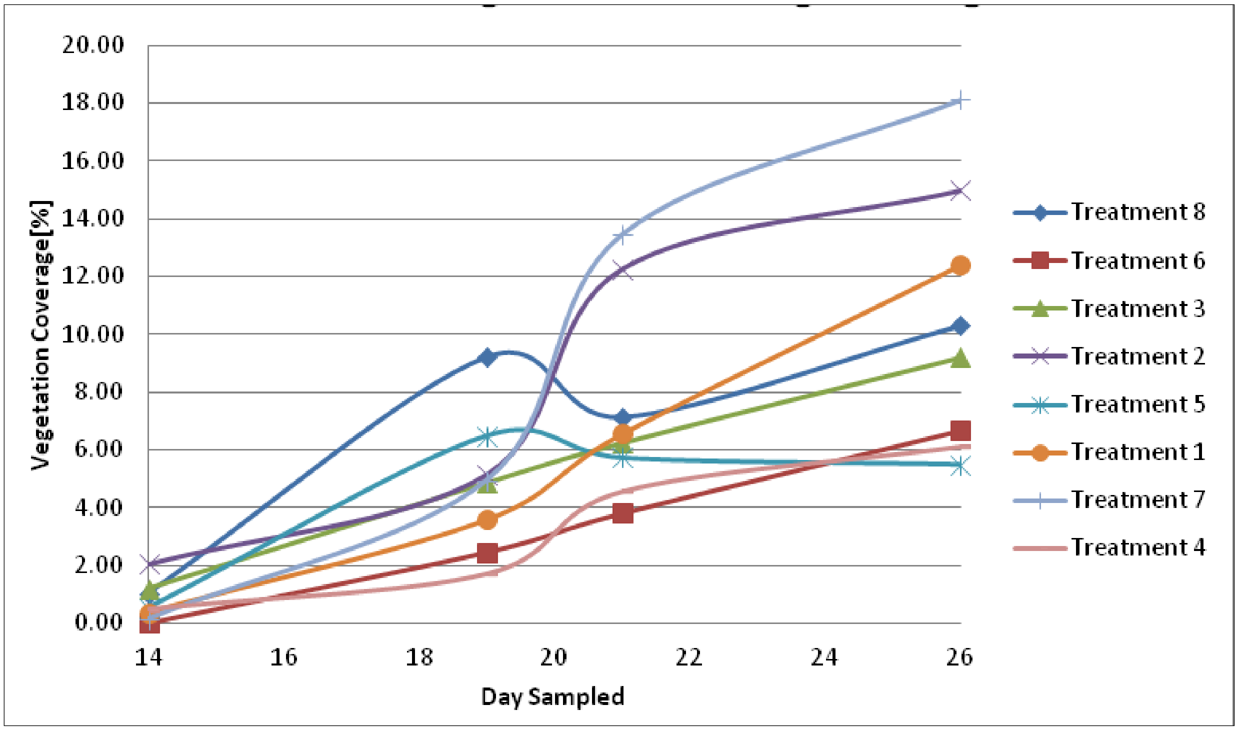

Figure E-12. Average vegetation coverage trend by treatment.

Table E-9. Average total growth coverage of treatments.

Treatment		Average Total Growth Coverage (%)
No.	**Description**	
1	Bare ground	12.40
2	Recycled plastic TRM	14.98
3	Excelsior TRM	9.19
4	Net-free excelsior ECB	6.13
5	Double-net excelsior ECB	5.49
6	Double-net straw ECB	6.68
7	Compost	18.11
8	Light double-net excelsior ECB	10.29

Table E-10. Days at which statistically significant differences between treatment plots occurred (T1 and T7 are non-ECB treatments).

T1								
T2								
T3								
T4								
T5								
T6		14, 21						
T7				26	26	21		
T8	19			19		19		
Treatments	T1	T2	T3	T4	T5	T6	T7	T8

Table E-9 indicates that compost (Treatment 7) had the overall highest vegetation coverage percentage at the end of the demonstration. This result was not unexpected as compost has a high moisture-retention capacity and organic content with ready nutrient availability (all are factors that influence vegetation growth). The ECB with the highest percentage vegetation at the conclusion of the 26-day germination experiment was the recycled plastic TRM treatment (Treatment 2). The recycled plastic outperformed the other ECBs and TRMs by a large margin, having an average total coverage of 14.98%. It was determined, based on both observation and analysis, that compost was the most successful treatment in achieving vegetation coverage under these field-controlled settings. In areas where compost is readily available, is cost competitive when compared with ECBs life-cycle analysis, and is located away from areas of preferential water flow, compost use as ESC BMP should be given preference over ECBs.

The box plots for each treatment (Figure E-3 through Figure E-10) show the range in vegetation growth over the duration of the study. Table E-10 lists the results of an ANOVA comparison of the treatments between plots on specific days. Statistically significant ($p \leq 0.05$) differences are indicated in green. Under the conditions of this experiment, differences did exist between treatments on certain days, but at the conclusion of the germination study (Day 26), the differences between ECBs were no longer evident. Treatment 7 (compost) fared well in the study under controlled conditions. Bare ground, which performed well in the study, is excluded because it had a lower sprout-to-surface distance to breach before being detected by the analysis method. Additionally, while bare ground may be ideal for growing vegetation under no/low slope conditions, steeper slopes have greater erosion potential and bare ground conditions are higher risk under those circumstances.

It is important to note that there are limitations in the analysis performed in this study. The *ASSESS* program, which was used to determine the percent of vegetated coverage for the treatment plots, takes into account only the top surface's visual layer. In this study, this approach gave the bare ground treatment an advantage during the initial days of the study; since the grass seeded on bare ground did not have to grow through a protective layer such as compost or ECB, the fescue was immediately visible, unlike other treatments. As the study progressed, this difference disappeared

As with any study that is performed within in-situ conditions, there are uncontrollable factors (e.g., rainfall frequency). Nevertheless, this demonstration and evaluation provides insightful data. It should be noted that the recommendation for establishing tall fescues and similar grasses is to plant them in the spring and fall rather than the middle of the summer (when this study occurred) when the seedlings are generally placed in high-stress situations.

APPENDIX F:
VEGETATION COVERAGE ANALYSIS

ASSESS is an image-analysis software tool used to determine plant characteristics and disease pathology. Images are taken in the field using digital photography and brought back for analysis. The images are taken using a 1-m quadrat[2] at a constant distance to ensure image analysis consistency. The software performs the analysis based on color/hue. Therefore, it is important during image capture to control for lighting as much as possible, although this can be corrected to a degree. The process for vegetative coverage analysis is documented below to ensure that, if warranted, future studies can use this method if desired. This appendix documents the steps to perform a typical analysis using *ASESS* software.

1. Open the program (Figure F-1).

Figure F-1. *ASSESS* 2.0 "splash screen."

[2] A quadrat is a small, typically rectangular plot used to isolate a standard unit of area for study of the distribution of an item over a large area.

2. Select the "Agronomist" threshold panel (Figure F-2).

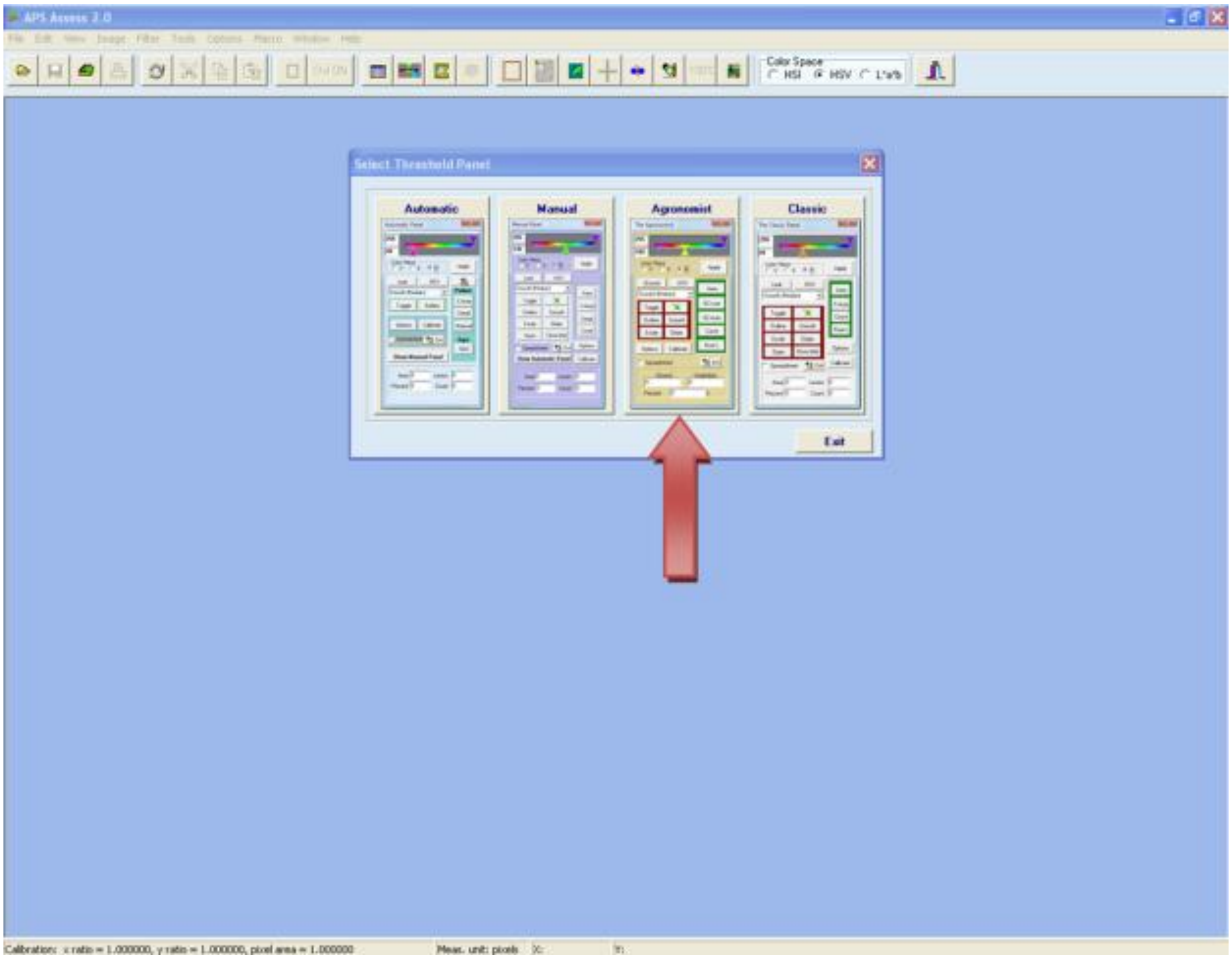

Figure F-2. *ASSESS* 2.0 "Agronomist" threshold panel.

3. Open the image to be analyzed by selecting it from the corresponding folder (Figure F-3).

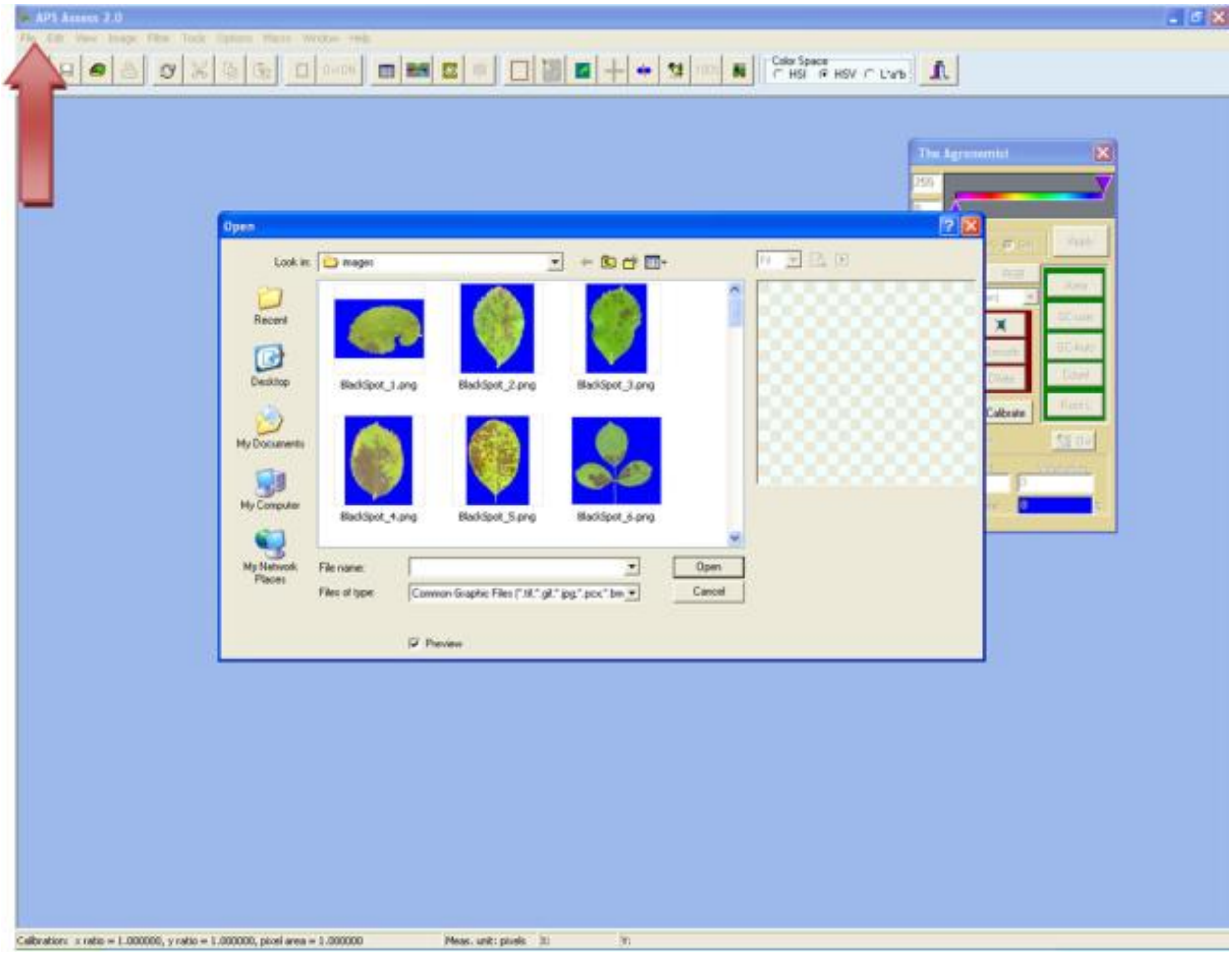

Figure F-3. ***ASSESS*** **2.0 folder selection screen.**

4. After image has been opened, zoom in or zoom out as necessary under "View" (Figure F-4).

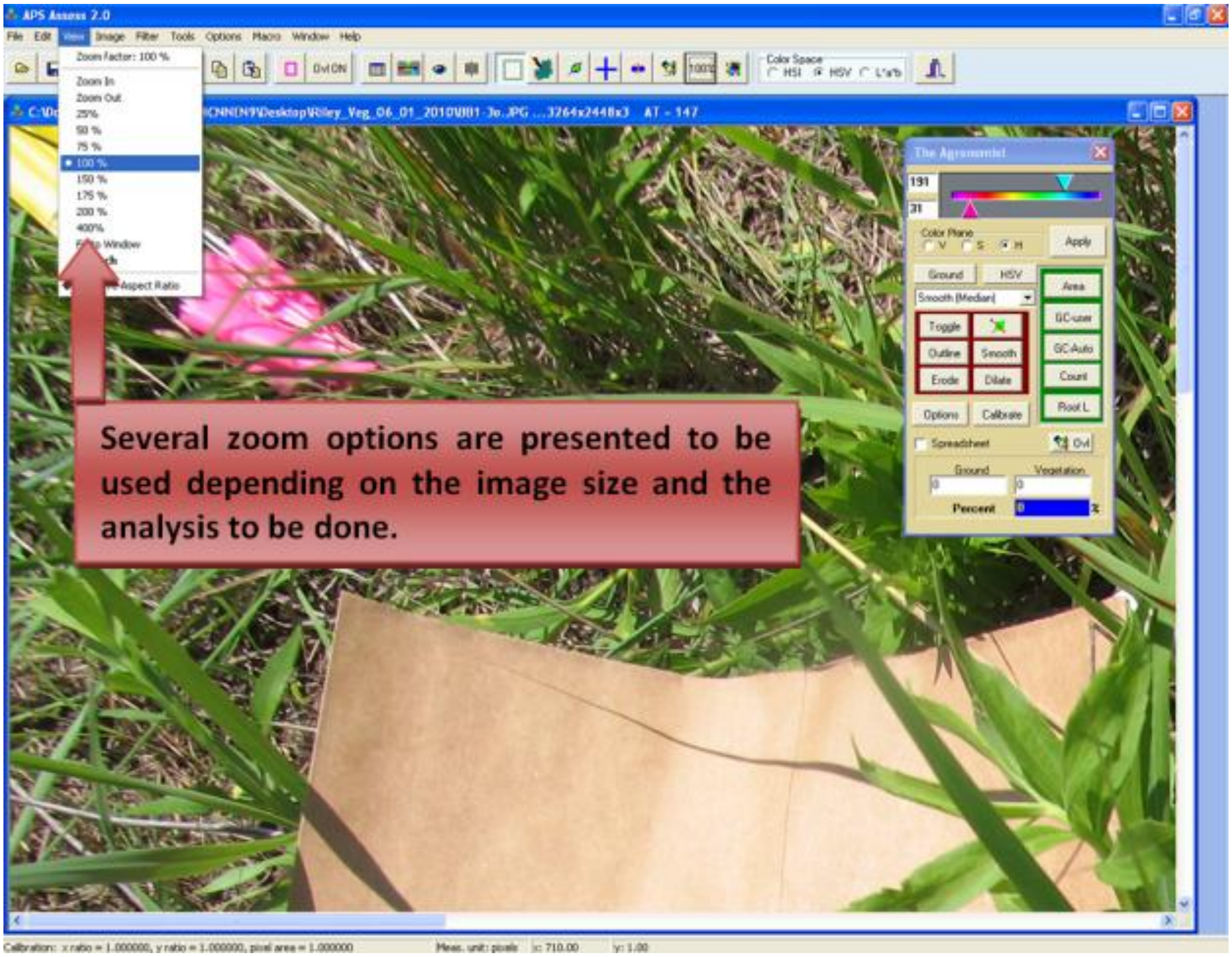

Figure F-4. *ASSESS* 2.0 zoom option.

5. Depending on the area of interest (AOI), choose a tool to select it. The AOI can be rectangular or may be designated with a freehand curve (Figure F-5).

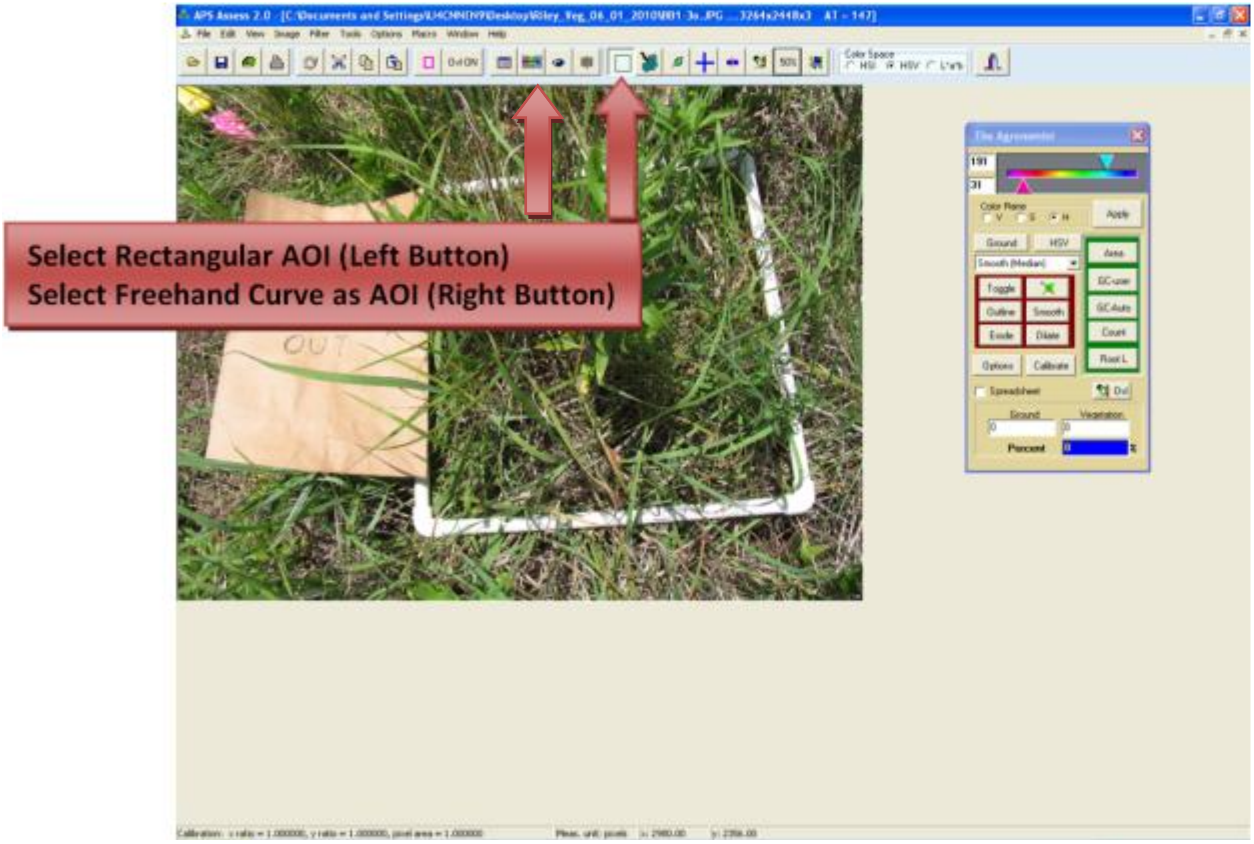

Figure F-5. *ASSESS* 2.0 AOI selection tool.

6. After the AOI has been selected, click on “GC-AUTO” on “The Agronomist Panel” (Figure F-6).

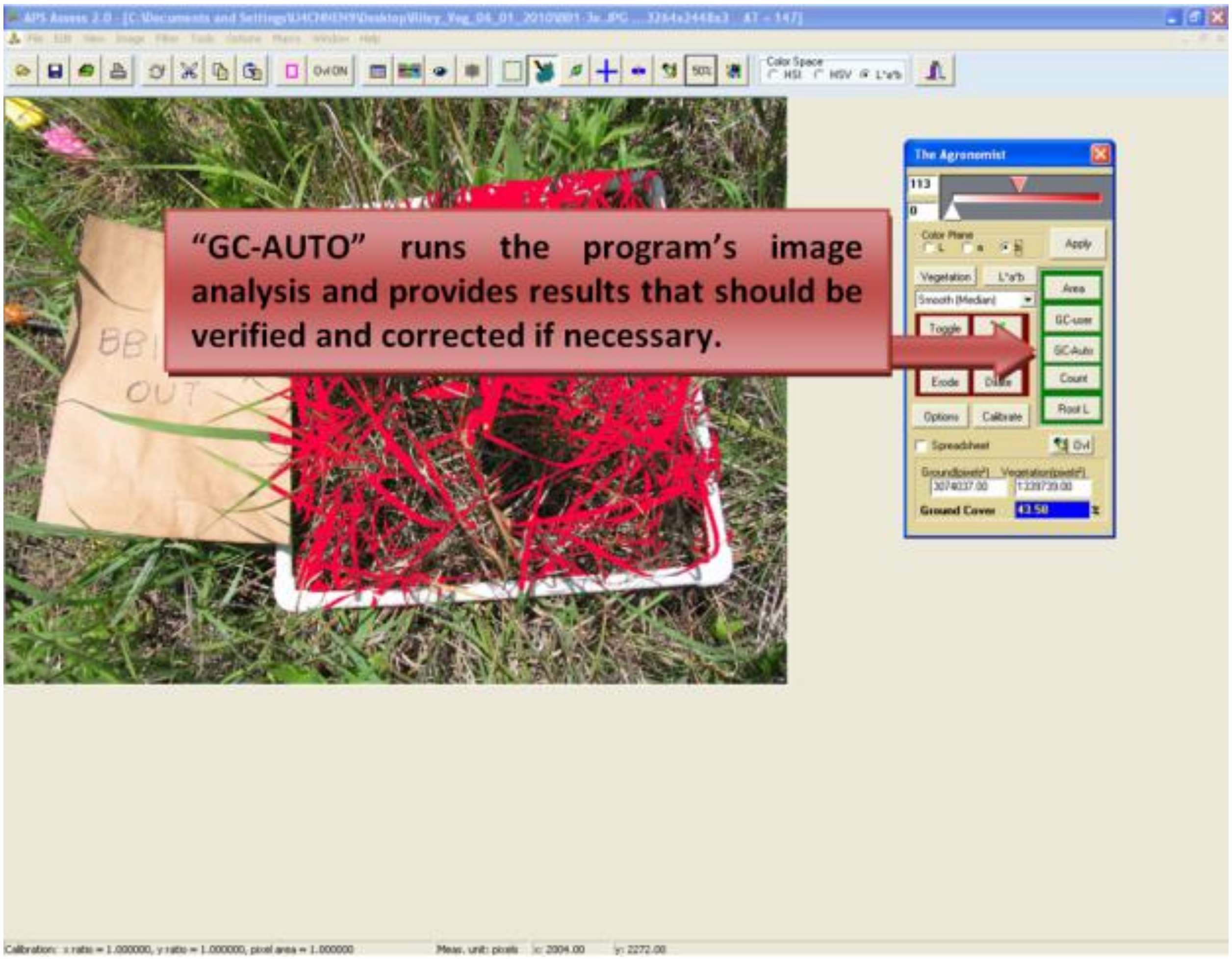

Figure F-6. *ASSESS* 2.0 “GC-Auto” image analysis.

7. Take note of the image name, "Ground Cover %" and its corresponding "spectrum" (Figure F-7).

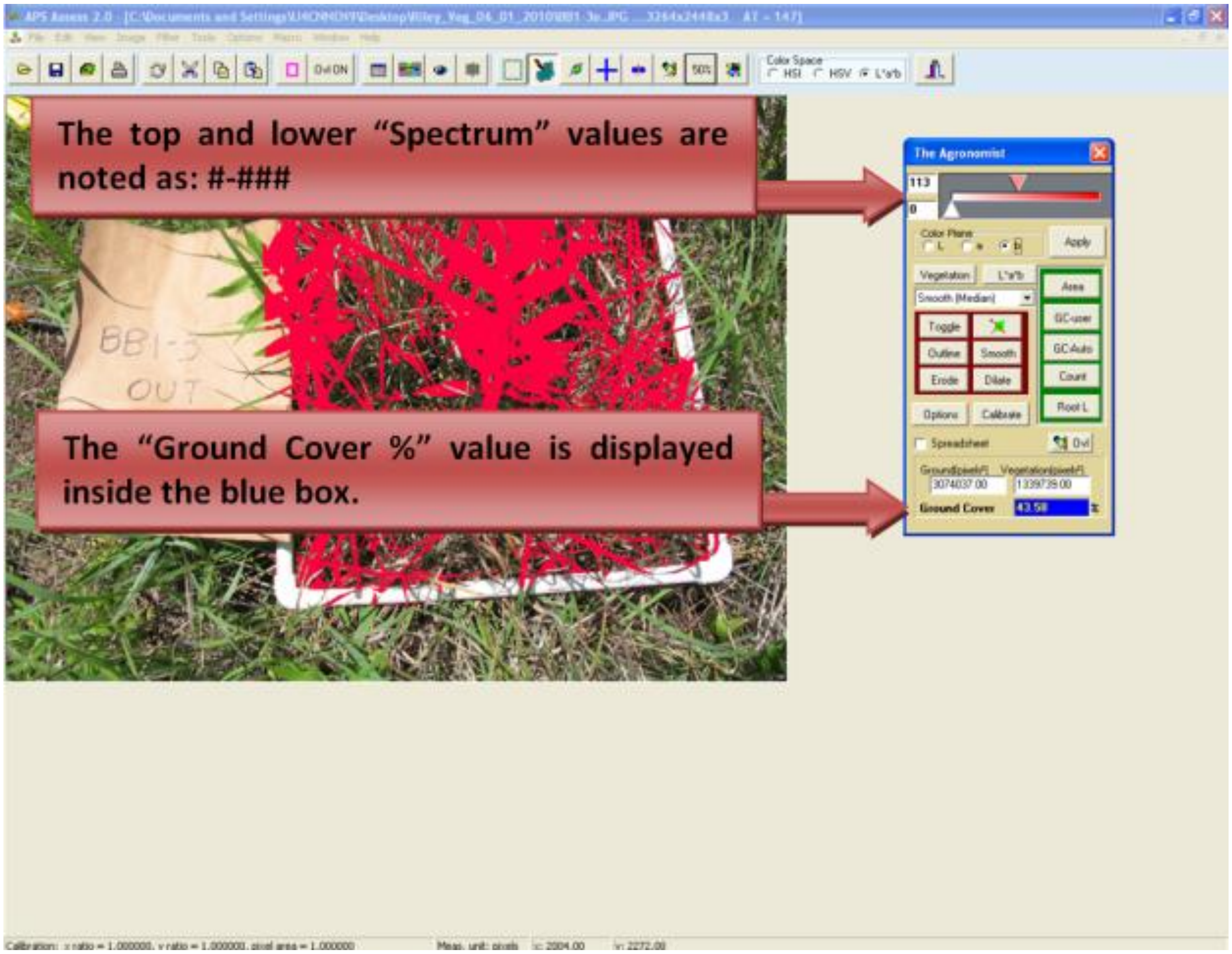

Figure F-7. Resulting ground cover values.

8. Toggle between the overlay (red layer) and original image modes to verify that most of the vegetation was accounted for in the resulting "Ground Cover %" (Figure F-8).

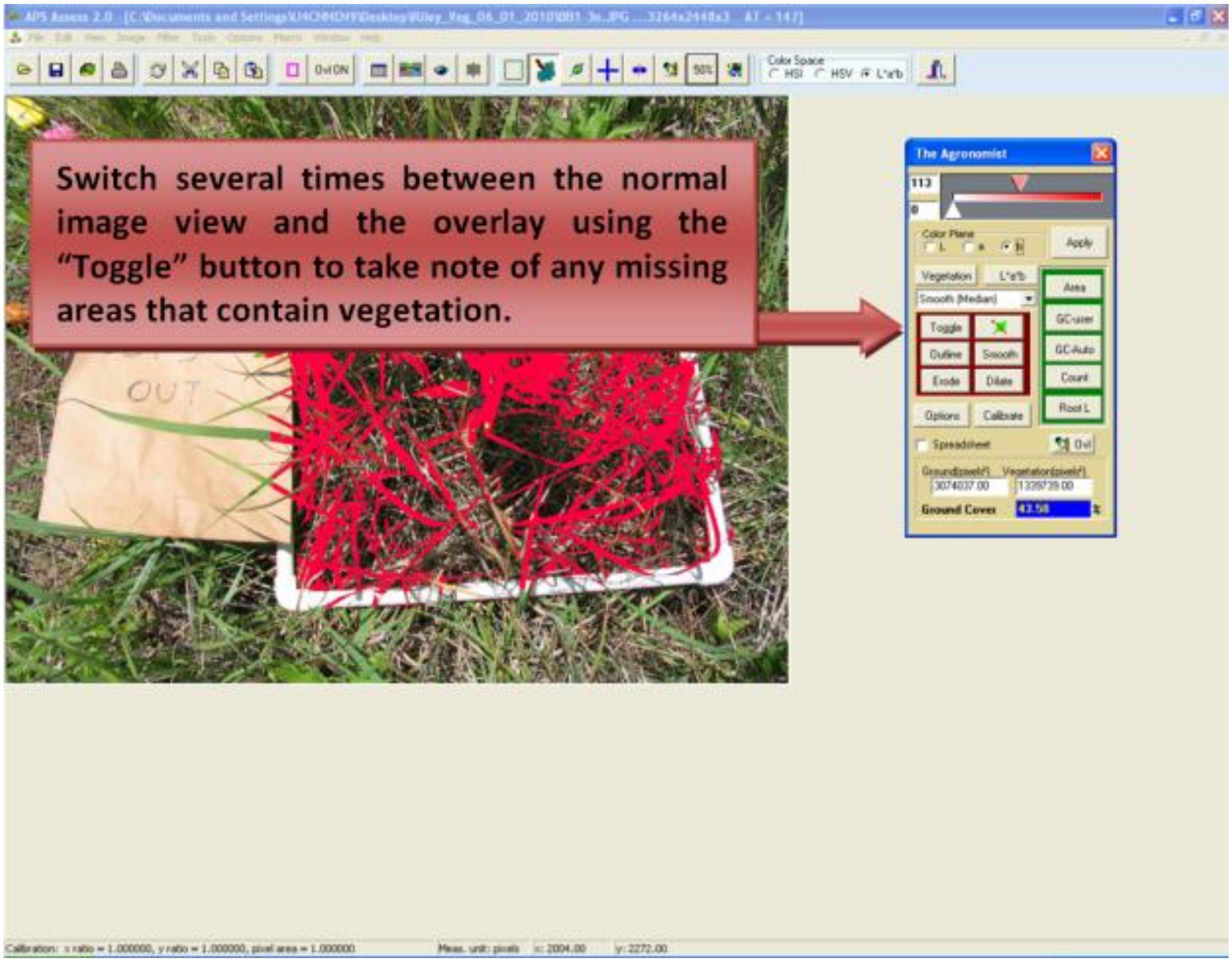

Figure F-8. Overlay and original image toggle.

9. It is likely that not all the vegetation was accounted for in the resulting "Ground Cover %." This can be corrected by increasing the upper "Spectrum" value (Figure F-9).

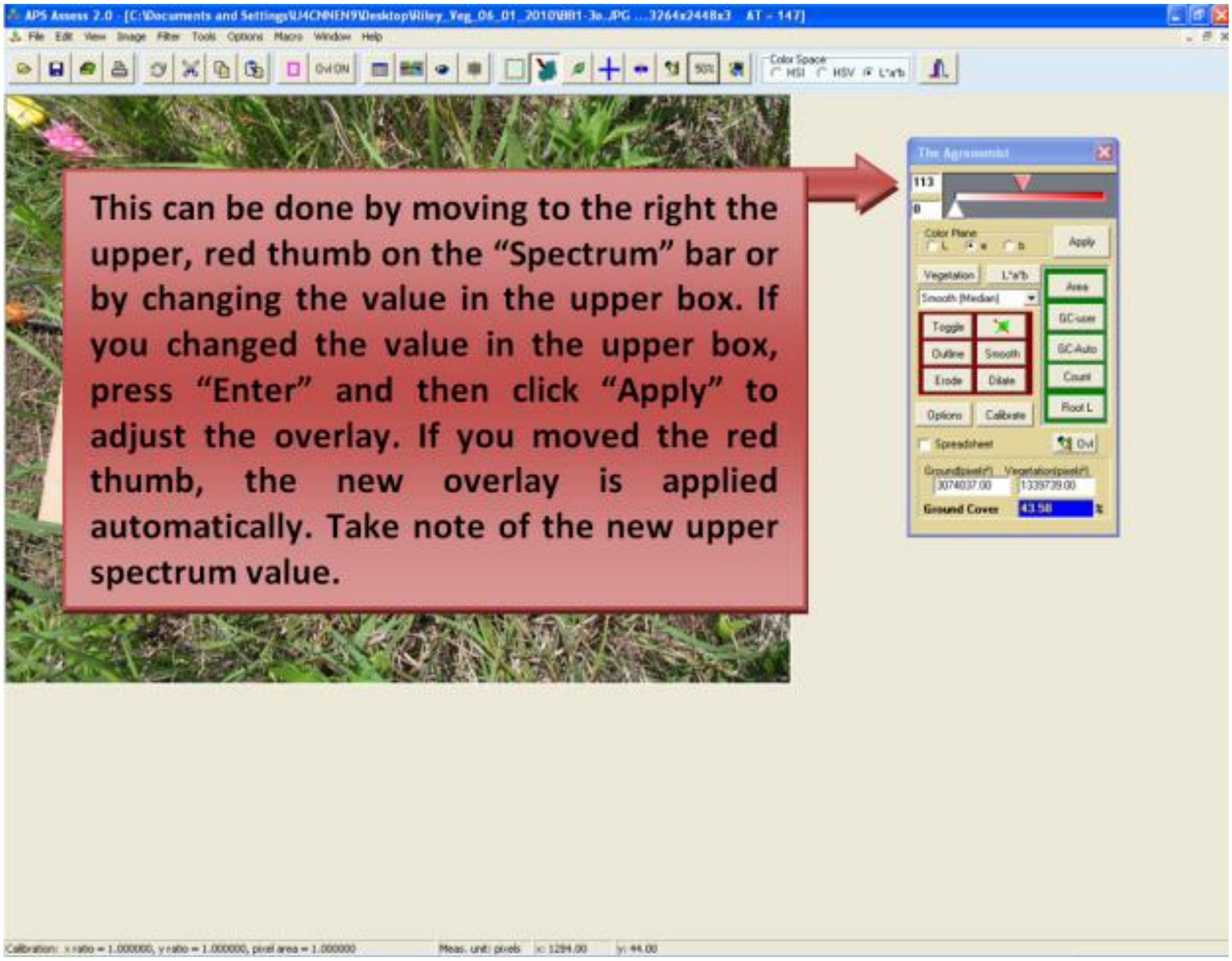

Figure F-9. Adjusting upper spectrum value.

10. After adjusting the “Spectrum” to its new value, click on “GC-user” to run the program again (Figure F-10).

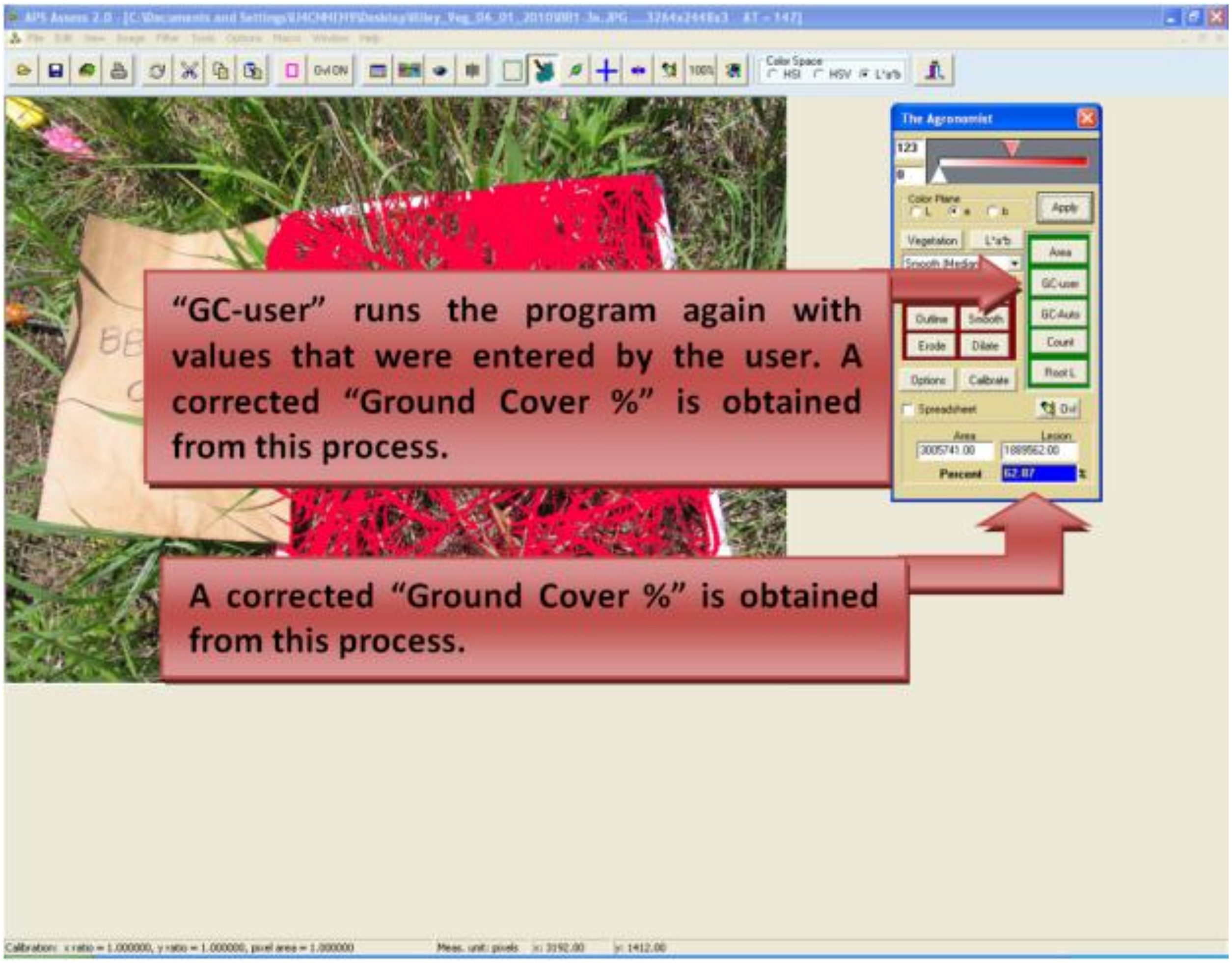

Figure F-10. Rerun the progam using “GC-user.”

11. Obtain the "Ground Cover %" of the forbs by lowering the upper spectrum value (similar to Step 9) until only the desired vegetation is selected (Figure F-11).

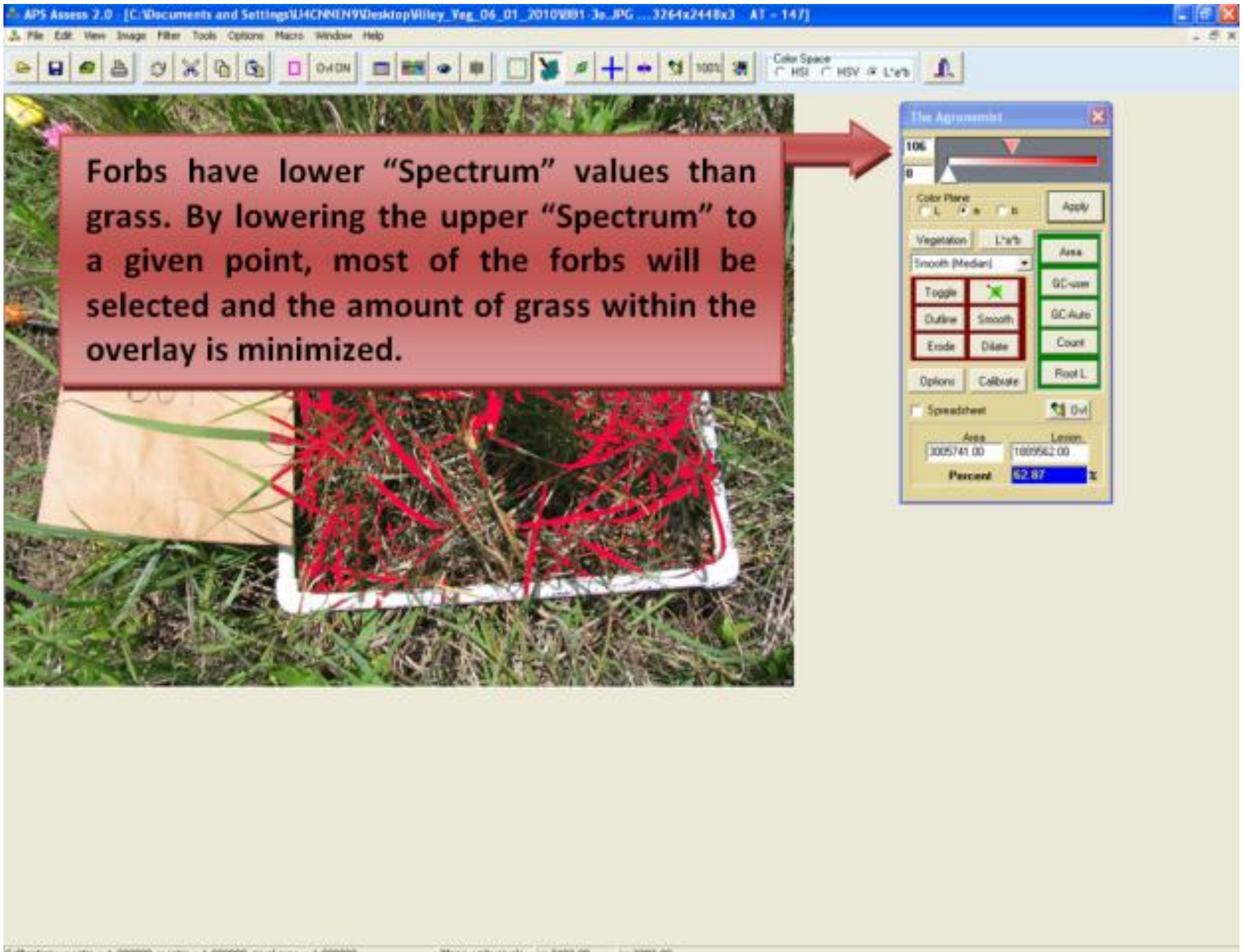

Figure F-11. Lowering the upper spectrum value to select the desired vegetation.

12. Repeat Step 10 to obtain the "Ground Cover %" of forbs and take note of it.

13. Subtract the "Ground Cover %" of forbs from the "Ground Cover %" of the total vegetation to obtain the "Ground Cover %" of the grasses.
$Grass\ Ground\ Cover\ \% = Total\ Ground\ Cover\ \% - Forbs\ Ground\ Cover\ \%$

14. It is recommended to organize and keep track of all the image data (file names, "Ground Cover %" values and "Spectrum" values) in an MS Excel® Workbook (Figure F-12).

***ASSESS* 2.0 Photo-analysis: [Location] (Date)**								
[Creator]								
[Company]								
[Contact Information]								
Image	**GC-Auto**		**GC-User**		**Forbs**		**Grasses**	
	Ground Cover (%)	**Spectrum**	**Ground Cover (%)**	**Spectrum**	**Ground Cover (%)**	**Spectrum**	**Ground Cover (%)**	**Spectrum**
BB1-1IN	50.51	0-123	N/A	N/A	15.43	0-105	35.08	N/A
BB1-1OUT	38.34	0-108	79.47	0-124	28.95	0-104	50.52	N/A
BB1-2IN	32.84	0-110	49.53	0-121	27.91	0-107	21.62	N/A
BB1-2OUT	40.76	0-117	58.95	0-124	21.96	0-107	36.99	N/A
BB1-3IN	50.87	0-113	59.74	0-118	48.91	0-112	10.83	N/A

Figure F-12. Example Excel® workbook to organize and track image data.

APPENDIX G

NON-EXHAUSTIVE RESOURCES LIST

Non-Exhaustive List of Manufacturers

A partial list of major manufacturers of reinforced vegetation products is listed below. This list is not exhaustive and does not constitute an endorsement of these products by the federal government.[3]

American Engineered Fabrics (http://www.usfabricsinc.com)

American Excelsior Company (www.americanexcelsior.com)

BOOM Environmental Products (www.boomenviro.com)

Contech Engineered Solutions LLC (http://www.conteches.com)

DeWitt Company (http://www.dewittcompany.com)

East Coast Erosion Control (www.eastcoasterosion.com)

Enviroscape ECM (www.strawblanket.com)

Erosion Control Blanket (http://www.erosioncontrolblanket.com)

F.P. Woll & Company (http://www.fpwoll.com)

Geo-Synthetics, LLC (http://www.geo-synthetics.com)

Granite Environmental, Inc. (http://www.erosionpollution.com)

Green Solutions (http://www.greensolutions.us)

Invisible Structures, Inc. (http://www.invisiblestructures.com)

L & M Supply (http://www.landmsupplyco.com)

North American Green (http://www.nagreen.com)

Volm (http://www.volmbag.com)

Western Fiber Company (http://www.westernfiber.com)

Non-Exhaustive List of Additional Internet Resources

Lawn Care Academy, "Climate Zones of the U.S."(http://www.lawn-care academy.com/climatezones.html).

Erosion Control – Official Journal of the International Erosion Control Association (http://www.erosioncontrol.com)

International Erosion Control Association (http://www.ieca.org).

[3] Note that the contents of this report are not to be used for advertising, publication, or promotional purposes. All products names and trademarks cited are the property of their respective owners.

APPENDIX H

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APPENDIX I

ACRONYMS AND ABBREVIATIONS

Term	**Definition**
ANOVA	analysis of variance
AOI	area of interest
AR	Army Regulation
CEERD	US Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
CWA	Clean Water Act
DoD	US Department of Defense
DC	District of Columbia
ECB	erosion control blanket
ECM	erosion control material
EISA	Energy Independence and Security Act of 2007
ERDC	Engineer Research and Development Center
ESC	erosion and sediment control
HQUSACE	Headquarters, US Army Corps of Engineers
IDOT	Illinois Department of Transportation
LEED	Leadership in Energy and Environmental Design
LLC	limited liability company
MDEP	Maine Department of Environmental Protection
NCDOT	North Carolina Department of Transportation
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System

Term	Definition
POC	point of contact
PWTB	Public Works Technical Bulletin
RECP	rolled erosion control product
TRM	turf reinforcement mat
UNEP	United Nations Environment Programme
USEPA	US Environmental Protection Agency
US	United States
USGBC	United States Green Building Council