GEOSYNTHETIC-STABILIZED VEGETATED EARTH SURFACES FOR ENVIRONMENTAL SUSTAINABILITY IN CIVIL ENGINEERING

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OUTLINE OF PRESENTATION

- Introduction
- Problems
- Solutions
- Research at KU
- Concluding Remarks

GEOSYNTHETICS

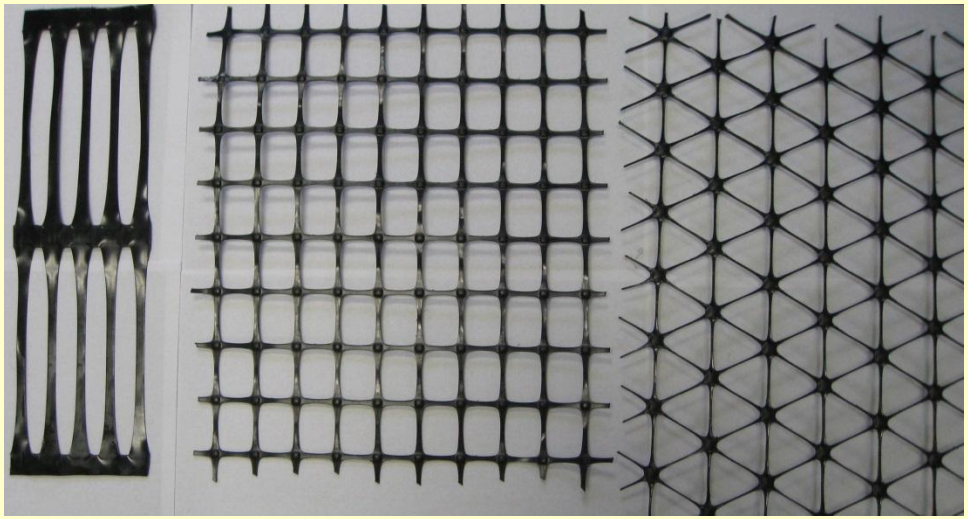
Manufactured polymer materials used for geotechnical applications

- Geotextile
- Geogrid
- Geocell
- Geomembrane
- Geonet
- Geosynthetic clay liner
- Geofibers
- Geofoam
- Geomat
- Geocomposite

THREE COMMONLY USED GEOSYNTHETICS

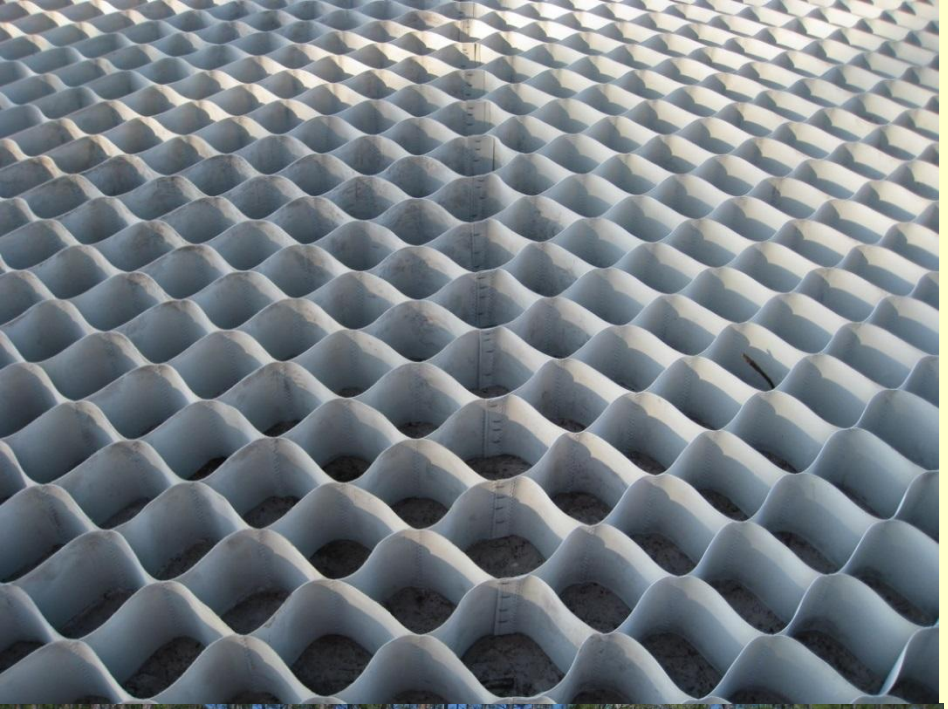
Geotextile (GT)

Geogrid (GG)



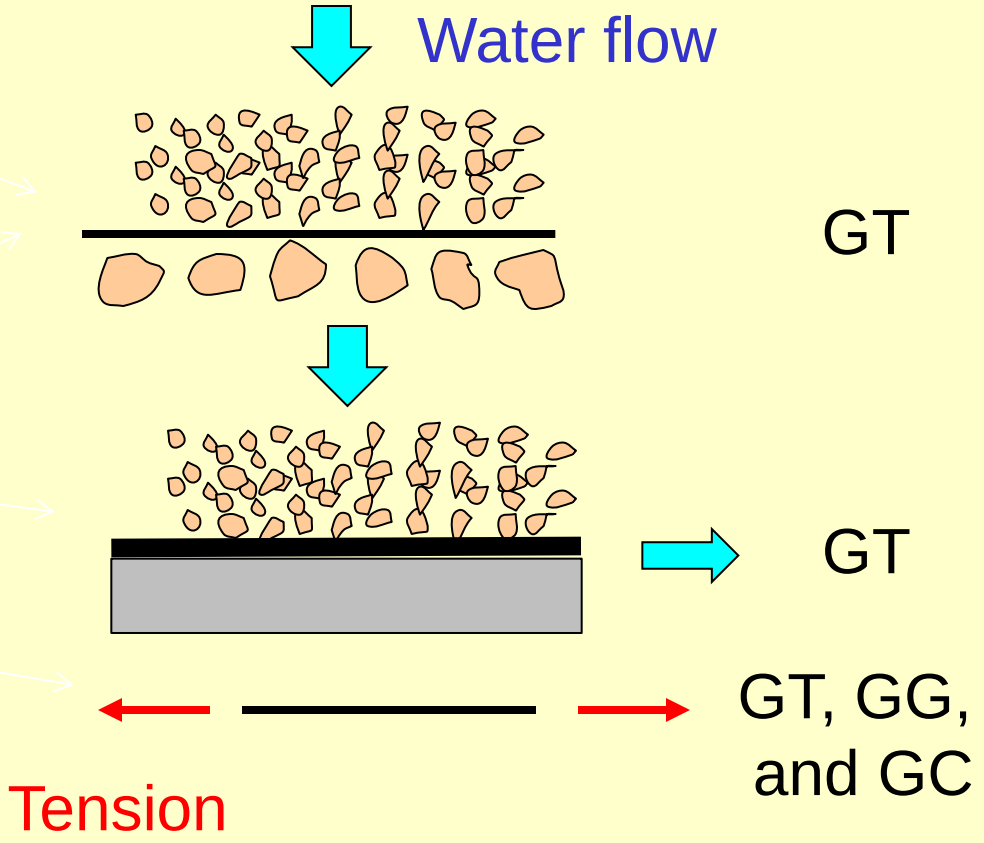
Geocell (GC)

INSTALLATION OF GEOCELL



MAIN FUNCTIONS OF GEOSYNTHETICS

- Separation
- Filtration
- Drainage
- Reinforcement
- Barrier
- Erosion protection



TYPICAL PROBLEMS FOR SLOPES AND UNPAVED SHOULDERS

Problems for slope surfaces

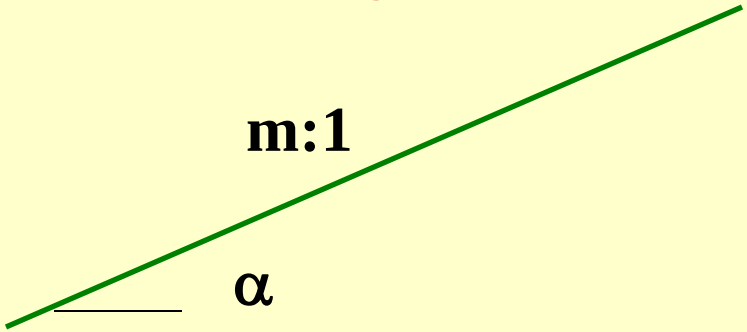
- Surficial slope instability
- Erosion

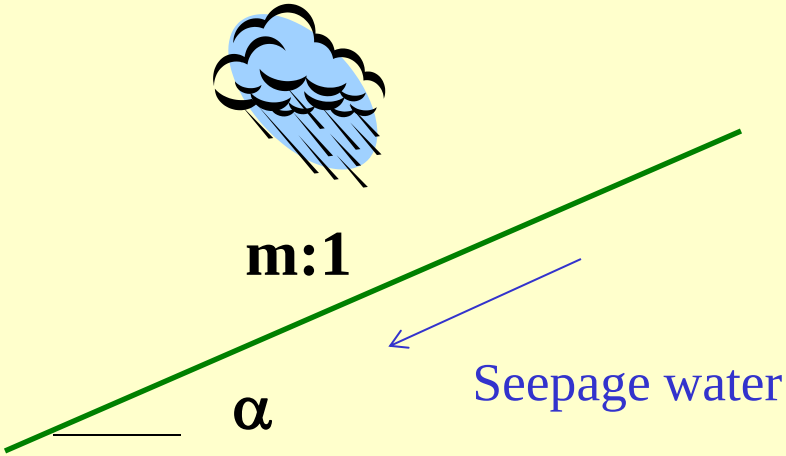
Problems for unpaved shoulders

- Rutting
- Erosion

STABILITY OF NATURAL SLOPE

Dry





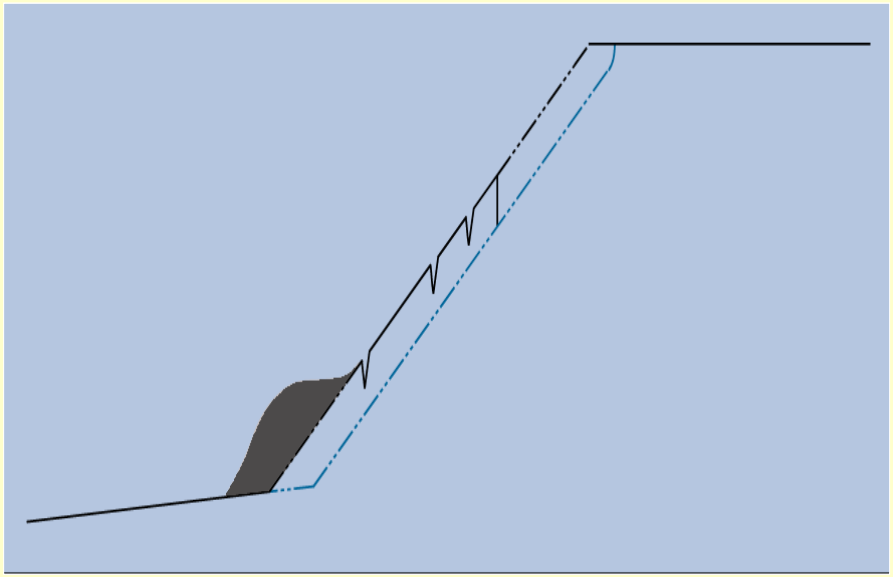
$$FS = \frac{tan\phi}{tan\alpha} \geq 1.0$$

$$FS \approx 0.5\frac{tan\phi}{tan\alpha} \geq 1.0$$

For typical soil, $\phi = 30^o$

2(H):1(V) slope (27º) — Stable — 4(H):1(V) slope (14º)

SURFICIAL SLOPE FAILURE



- **Shallow failure surface up to 1.2m (4ft)**
- **Failure mechanisms**
  - **Poor compaction**
  - **Low overburden stress**
  - **Loss of cohesion**
  - **Saturation**
  - **Seepage force**

SLOPE EROSION

- **Loss of soil mass**
- **Failure mechanism**
  - **Loss of vegetation cover**
  - **Soil washed out by water**

UNPAVED SHOULDER

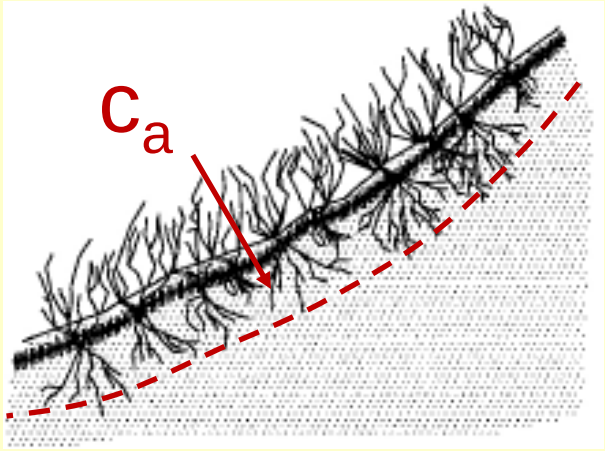
Rutting = accumulated permanent deformation due to traffic loading

Road edge drop-offs due to wind/water erosion

FHWA, USA, 2011 and 2013

BIO-STABILIZATION

$$FS \approx \frac{2c_a}{\gamma H \sin 2\alpha} + 0.5\frac{\tan\phi}{\tan\alpha}$$



Example:

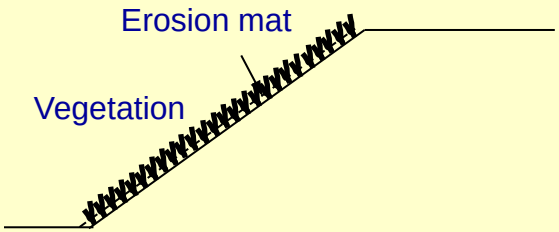
c_a = 50 psf, H = 2 ft, γ = 120 pcf, ϕ = 30^o

FS = 1.0

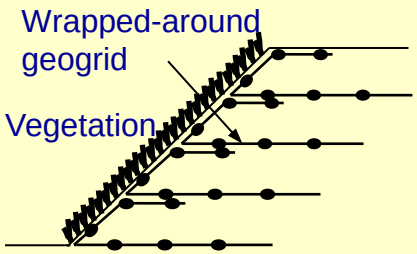
α = 40^o (1:1 slope, no-seepage condition)

α = 27^o (2:1 slope, seepage condition)

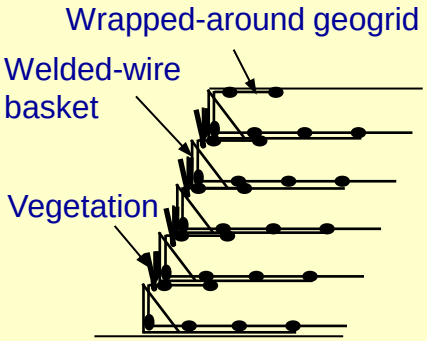
EXAMPLES OF GEOSYNTHETIC-STABILIZED VEGETATED EARTH SURFACES



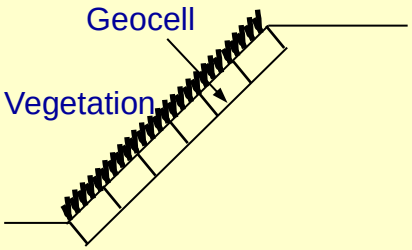
(a) Slope facing protected by erosion mat



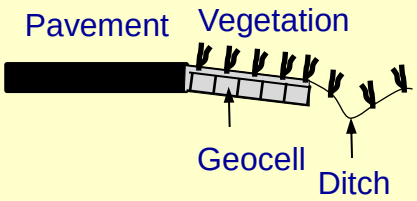
(b) Slope facing stabilized by wrapped-around geogrid



(c) Slope or wall facing stabilized by welded-wire basket and wrapped-around geogrid



(d) Slope facing stabilized by geocell



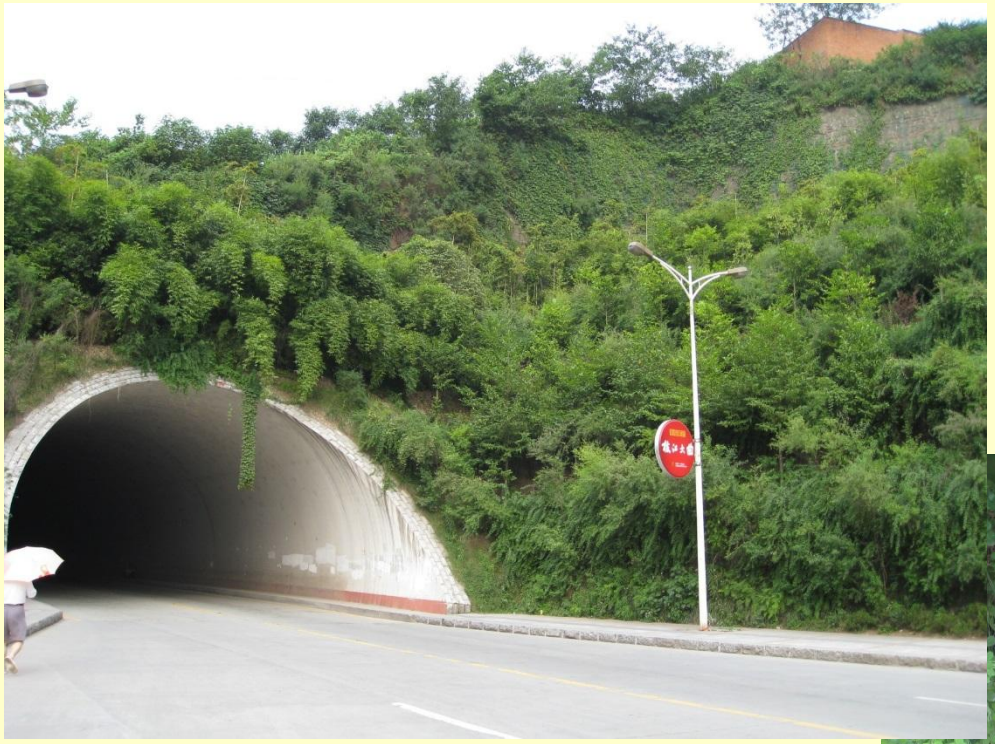
(e) Unpaved shoulders stabilized by geocell

EROSION CONTROL

- Erosion Mat or Blanket:
- Enhance seed germination and erosion resistance
- UV protected

Village at Westlake - Austin, TX

GEOGRID-WRAPPED SLOPE SURFACE



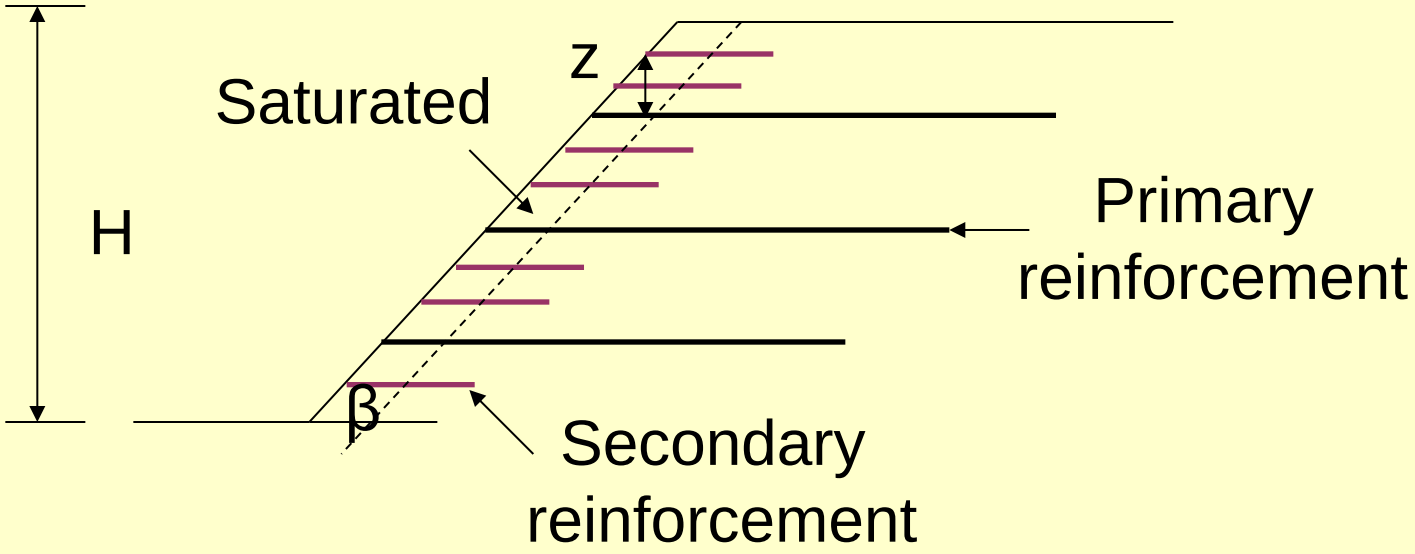
GEOGRID-WRAPPED WALL FACE

- **35°-70° inclination**
- **Stair-stepped shape with vegetation**
- **Welded-wire baskets**

R & B Chambers MSW Landfill Banks County, GA

GEOCELL-REINFORCED SLOPE FACE

SURFICIAL SLOPE STABILITY



$$FS = \frac{c'H + (\gamma_{sat} - \gamma_w) Hz \cos^2 \beta \tan \phi' + T_g (\cos \beta \sin \beta + \sin^2 \beta \tan \phi')}{\gamma_{sat} Hz \cos \beta \sin \beta}$$

T_g = summation of geosynthetic resisting force
(controlled by pullout or rupture)

Collin (2006)

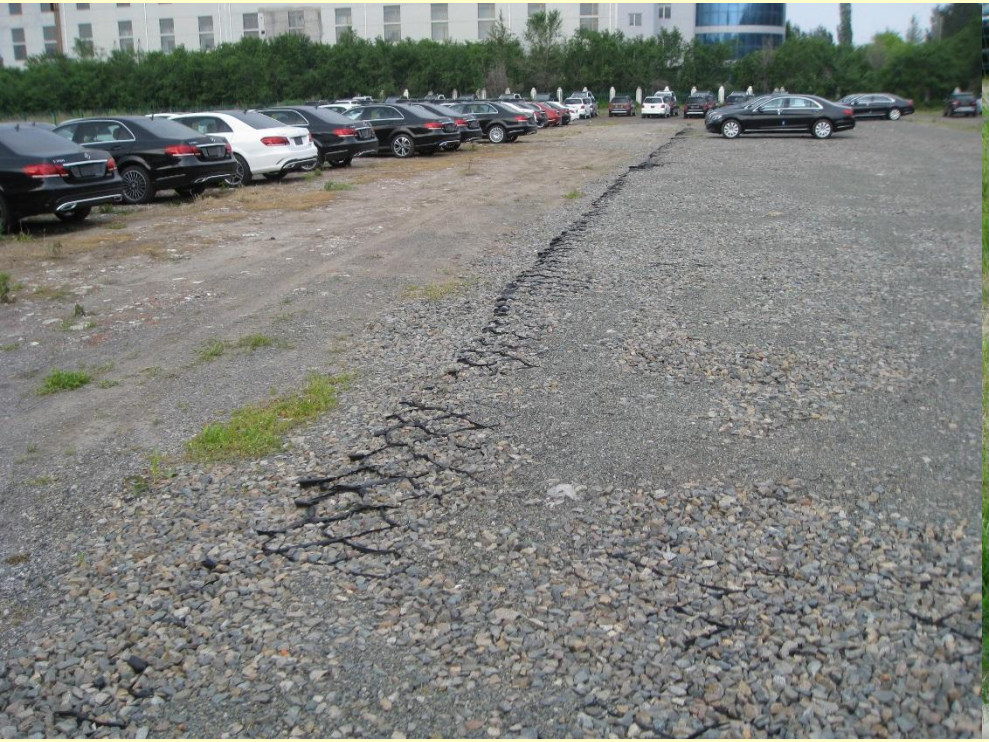
VEGETATED "GREEN" SHOULDER

- Reduce PM10
  - ➢ Reduce truck turbulent kinetic energy (i.e. dust control)
- Erosion control
  - ➢ Reduce wind/water erosion thus minimizing drop-off

Green shoulder requires fines and moisture, which makes the shoulder weak for traffic loading.

Geosynthetic reinforcement is expected to make shoulder stronger.

PARKING LOT WITH OR WITHOUT VEGETATION



Gravel parking lot

Vegetated parking lot

GREEN SHOULDER RESEARCH AT KU

Material used in this study

- Well-graded aggregate base – high strength but poor vegetation

- Native Top Soil (lean clay with organic content) – low strength but good vegetation

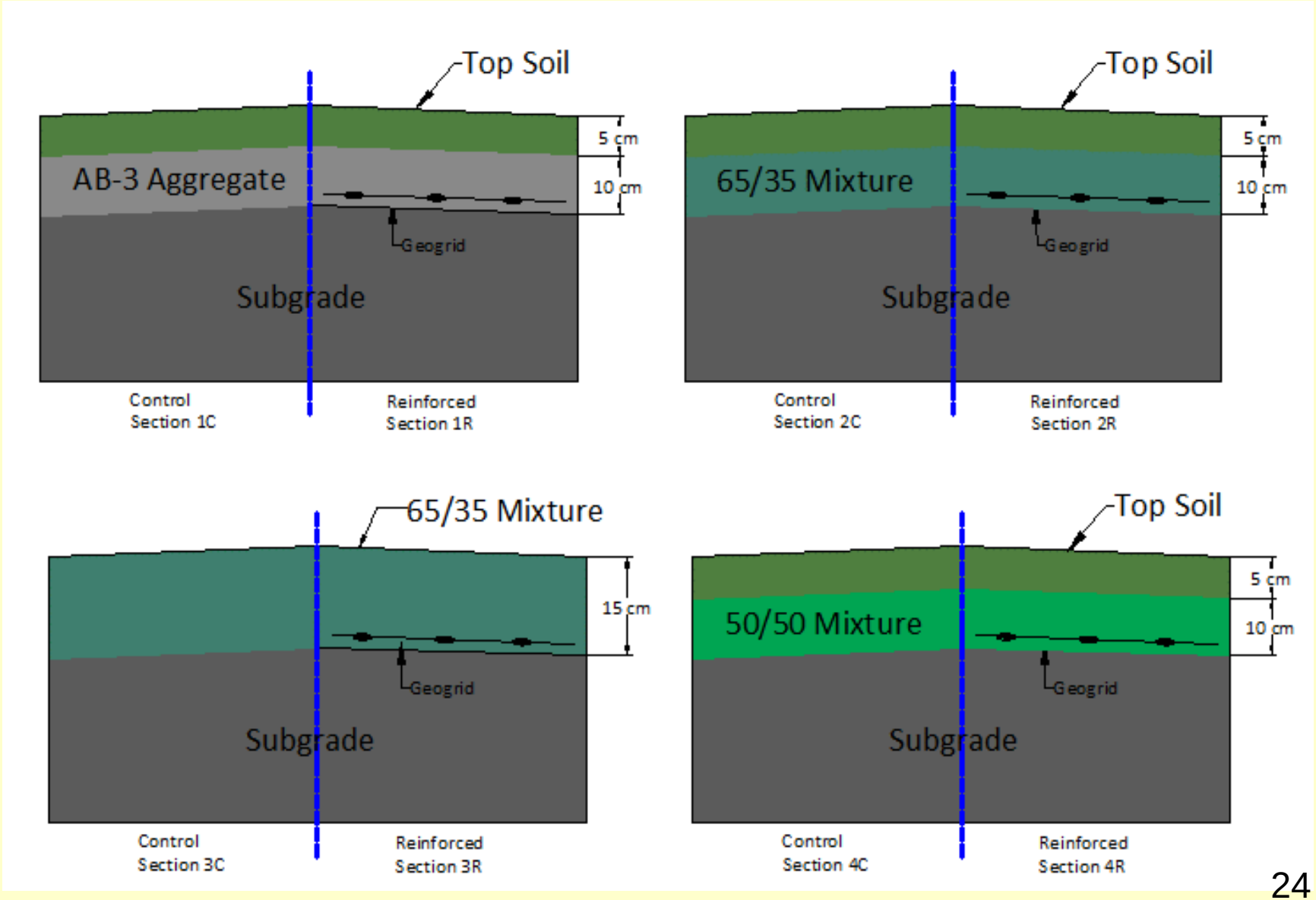
- Soil Mixture – sufficient strength and good vegetation
  - Mixture 1: 50% aggregate & 50% top Soil (by dry weight)
  - Mixture 2: 65% aggregate & 35% top Soil

- Triaxial geogrid and geocell

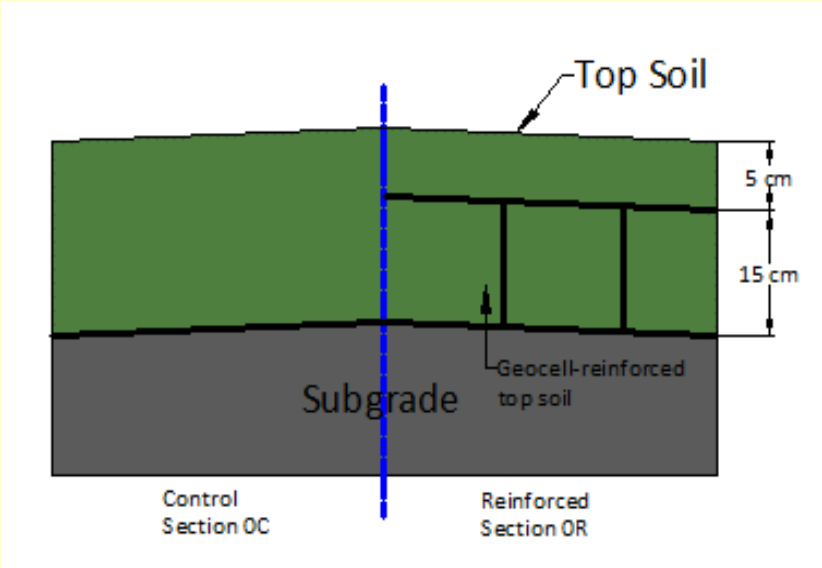
TEST SECTIONS

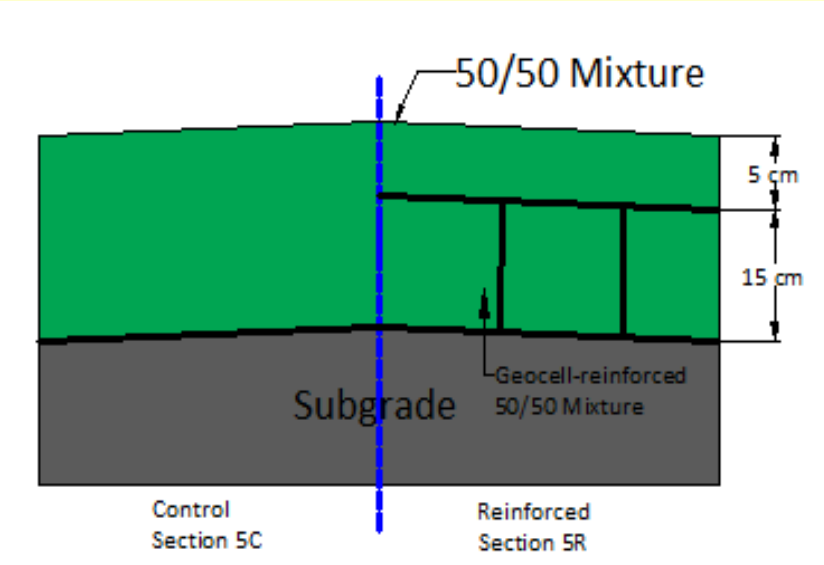
- 1.5 m by 1.5 m sections
- 1.6% slope for subgrade
- 4.2% slope for top surface
- Geotextile wrapped aggregate for side drainage

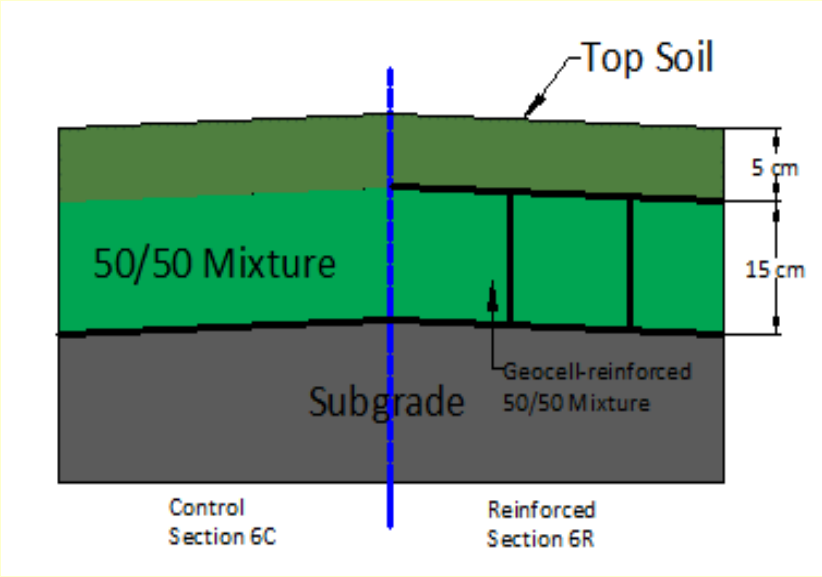
TEST SECTIONS

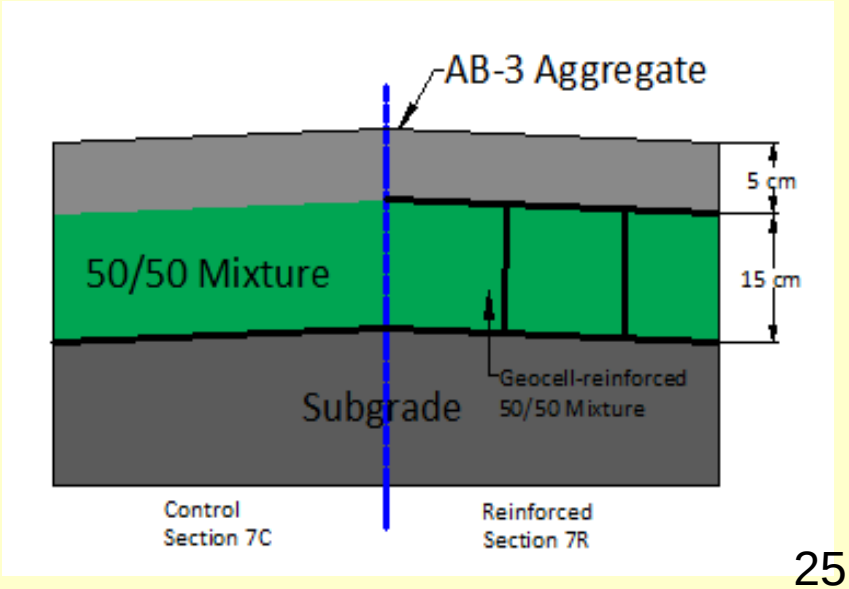


TEST SECTIONS

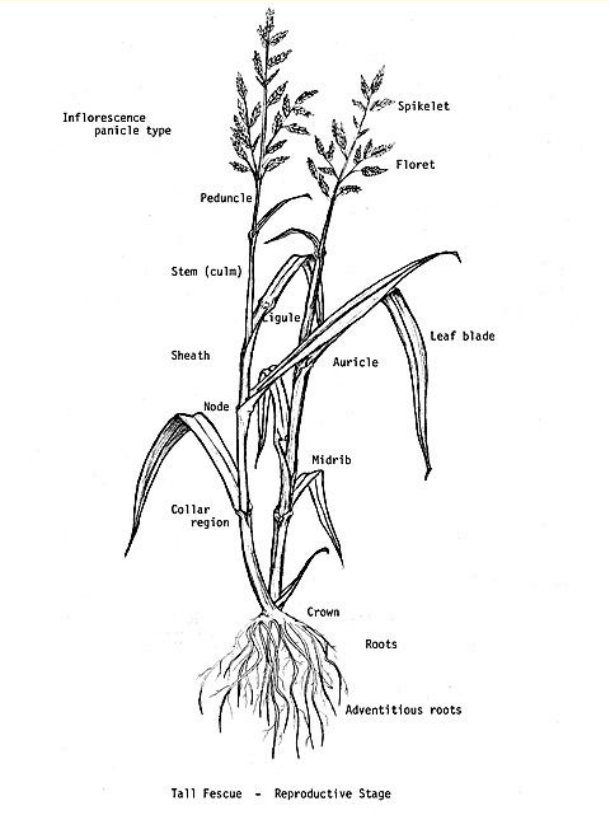








PRIMARY GRASS TYPES



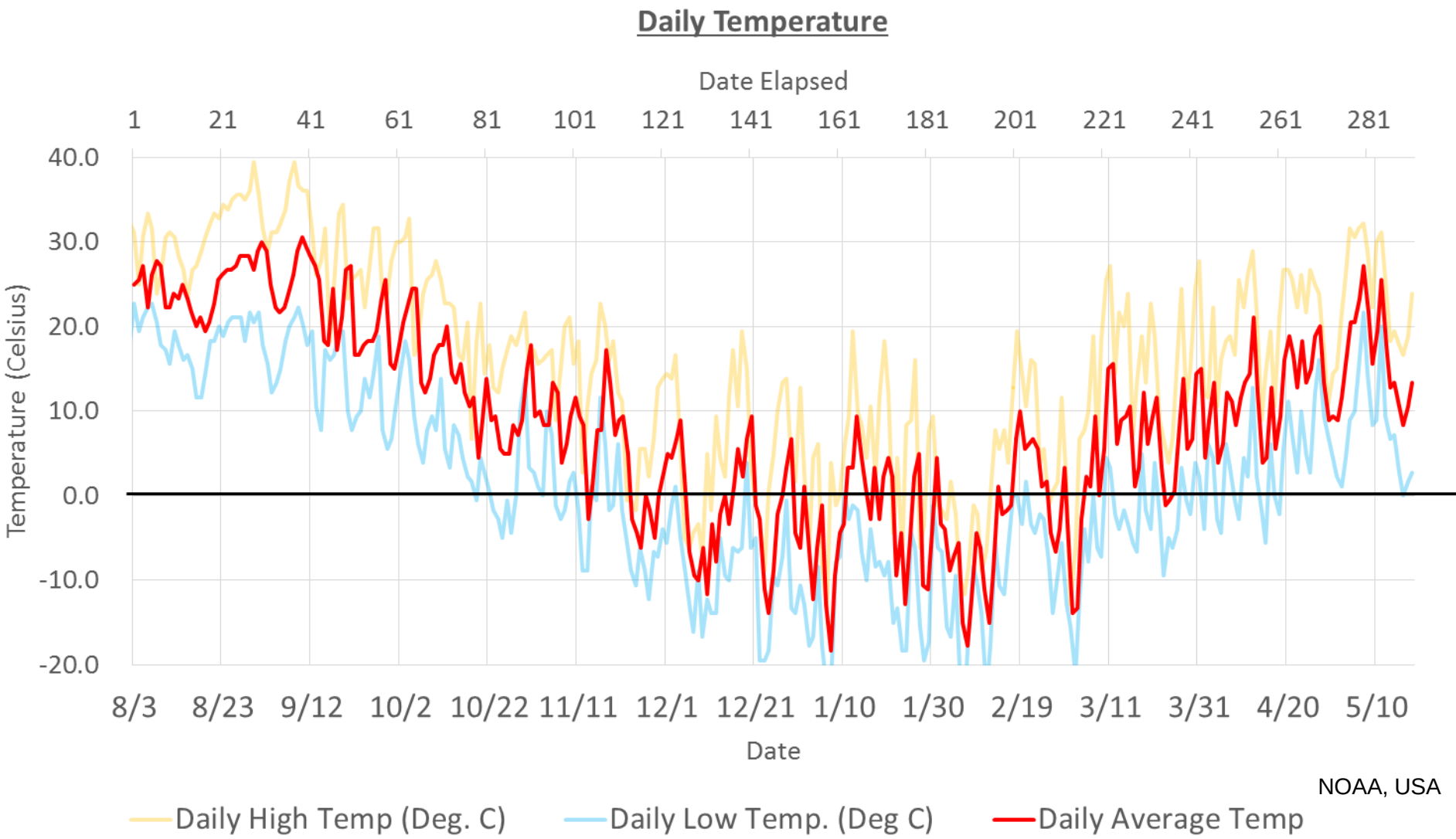
Oregon State University 2009

USDA 1950

Tall Fescue
(2.3 g/section)

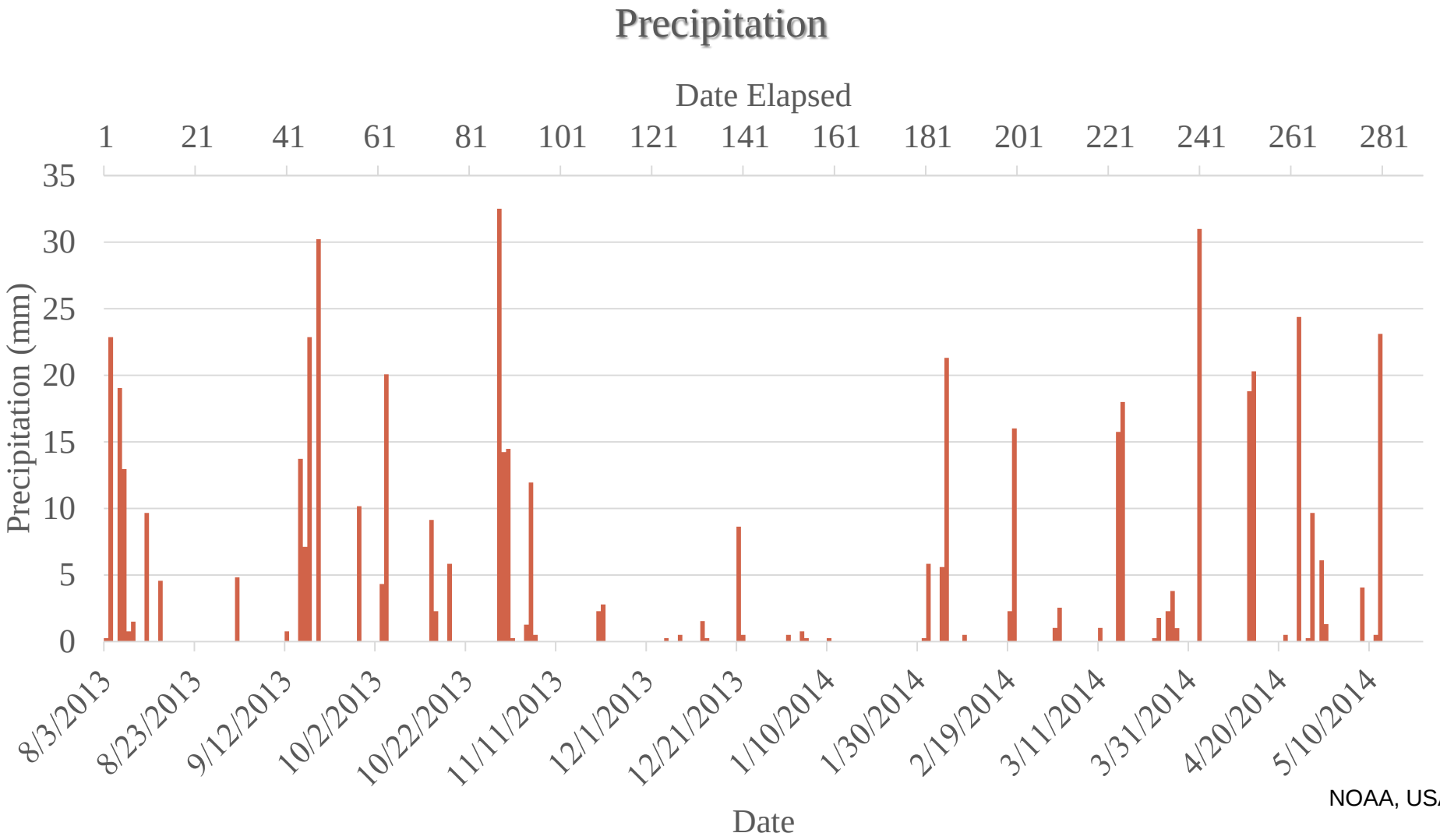
Perennial Ryegrass
(2.3 g/section)

TEMPERATURE



NOAA, USA

PRECIPITATION



NOAA, USA

All Test Sections

BLADE LENGTH

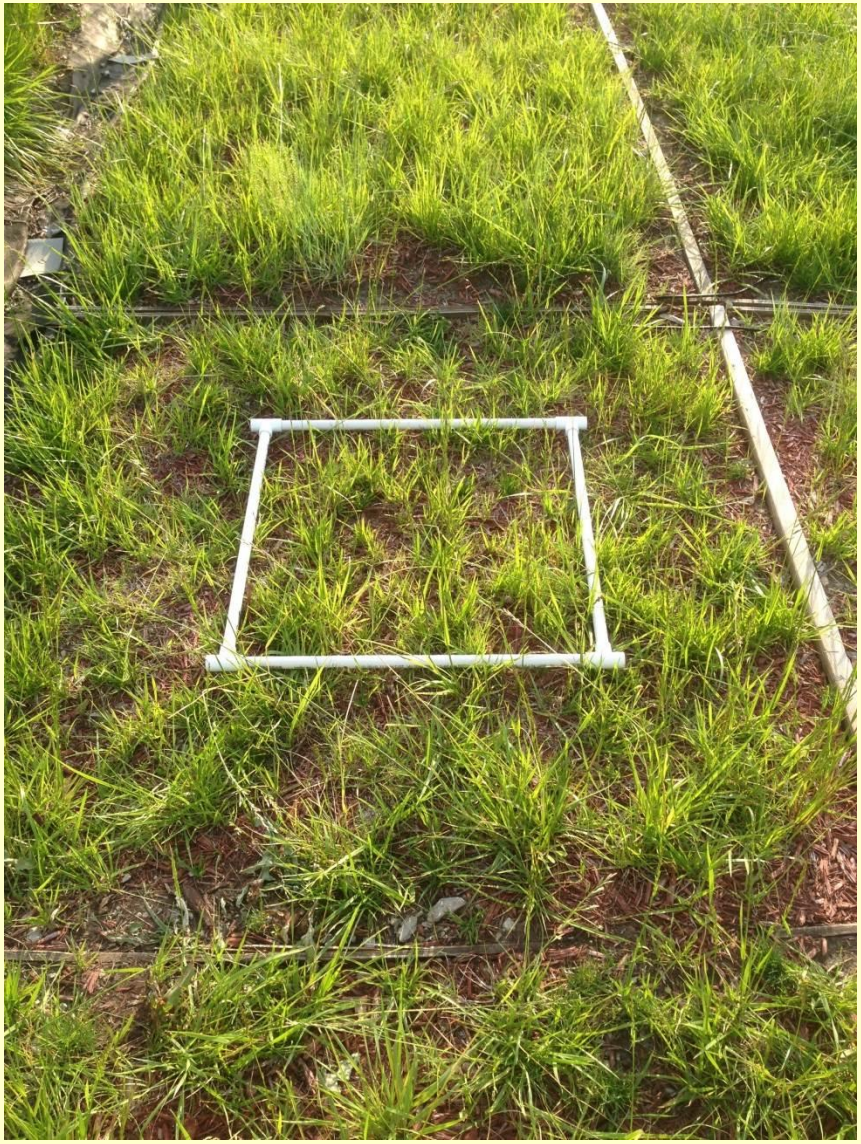
- The length of longest green leaf on a sprout

- 8 random samples per section

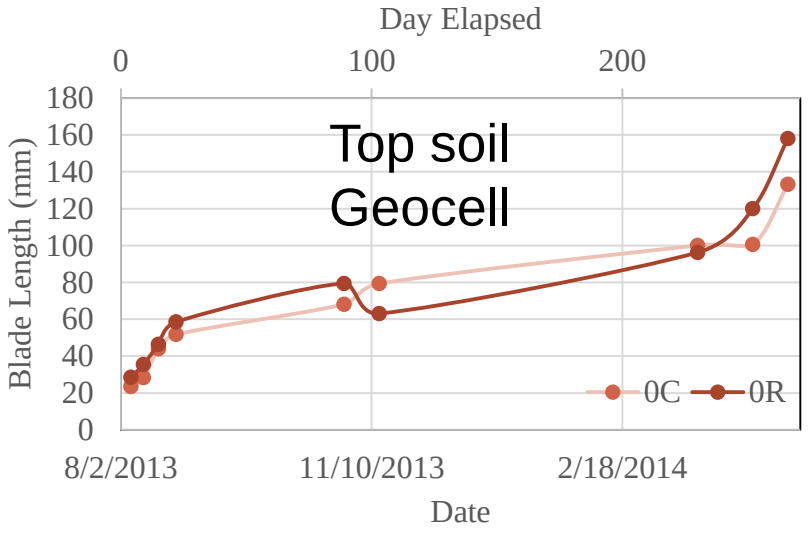
GRASS DENSITY

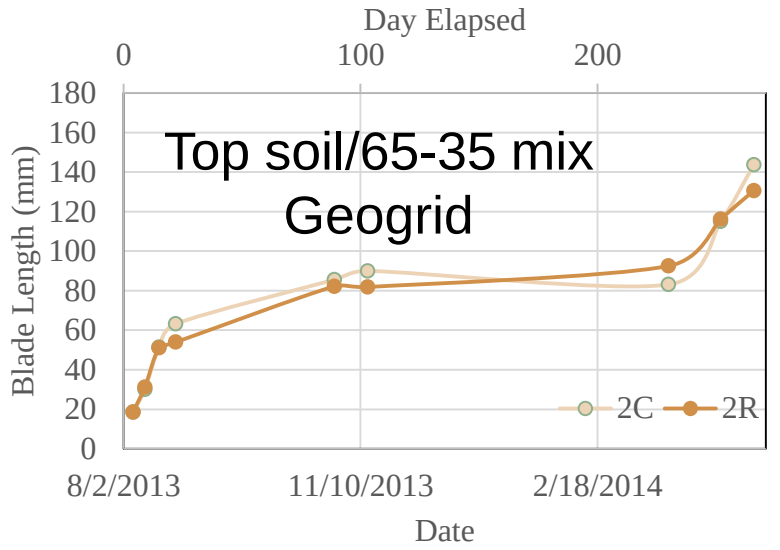
- Number of sprouts in a 0.6 m by 0.6 m square frame

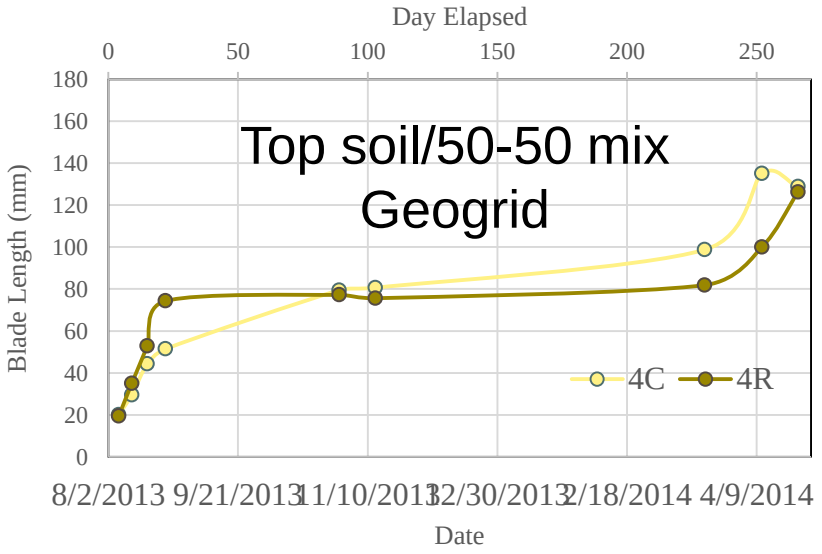
- The frame was placed on each section at random location

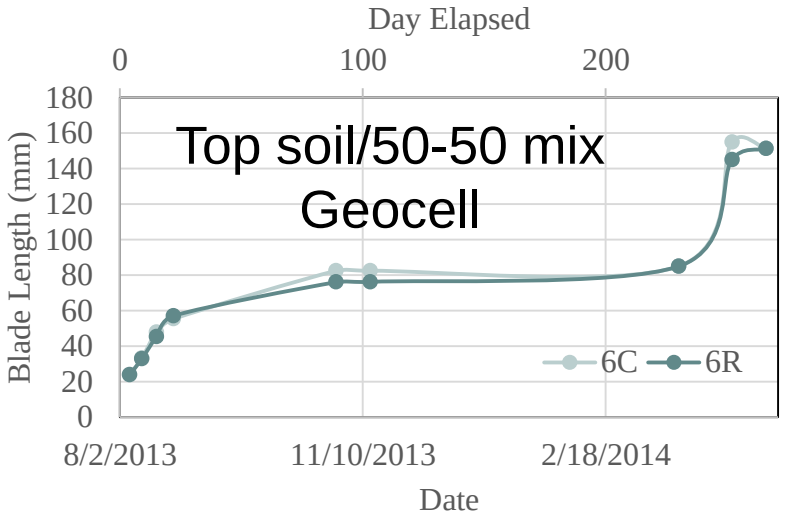


MEASURED BLADE LENGTH

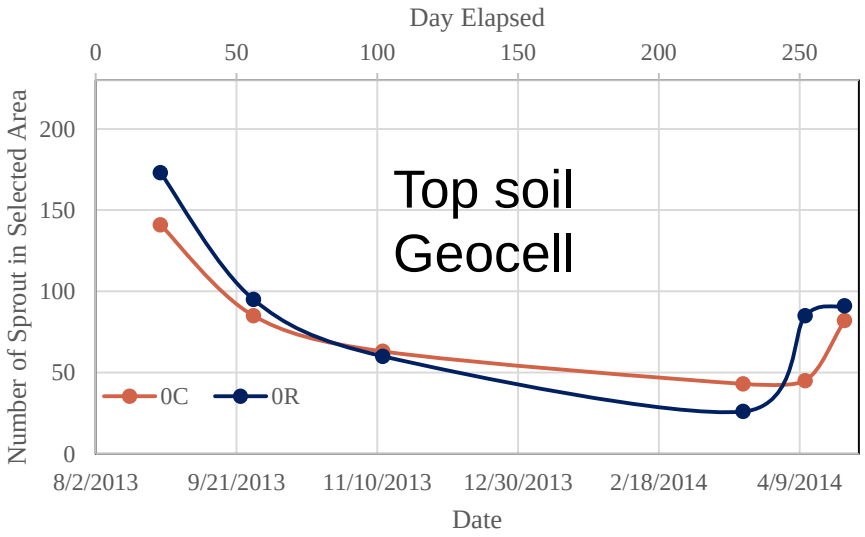


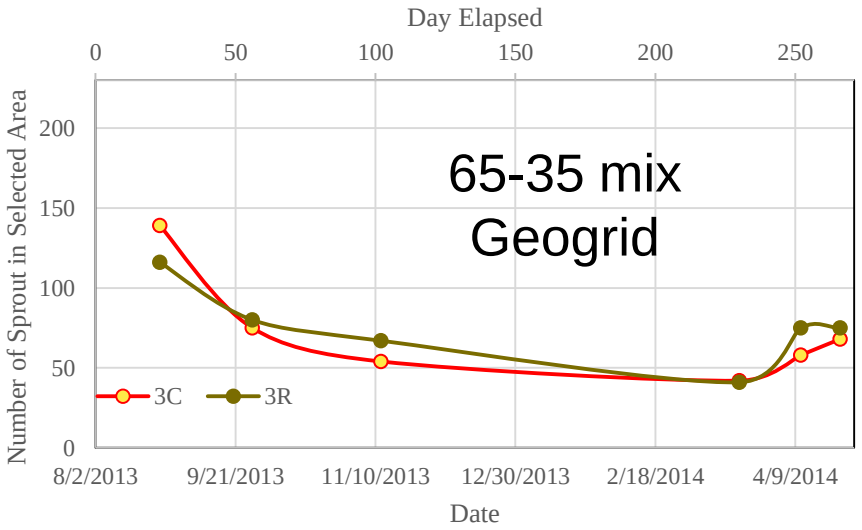


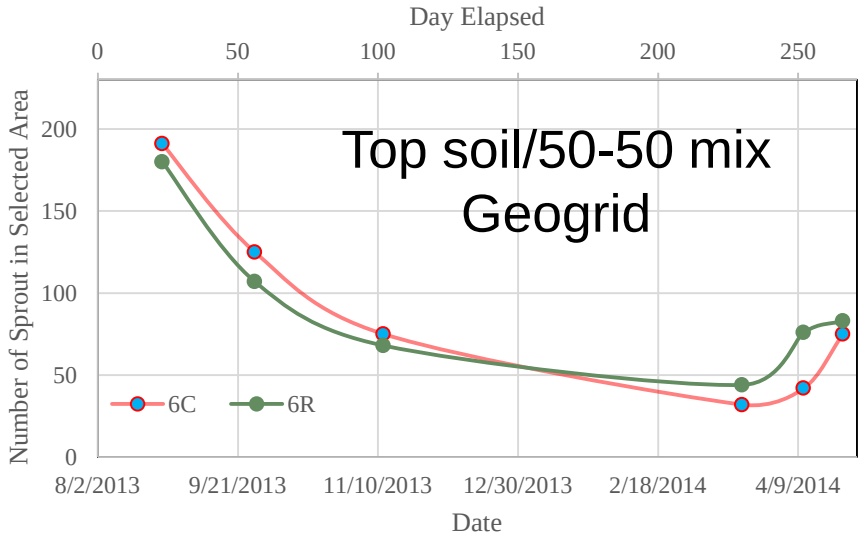


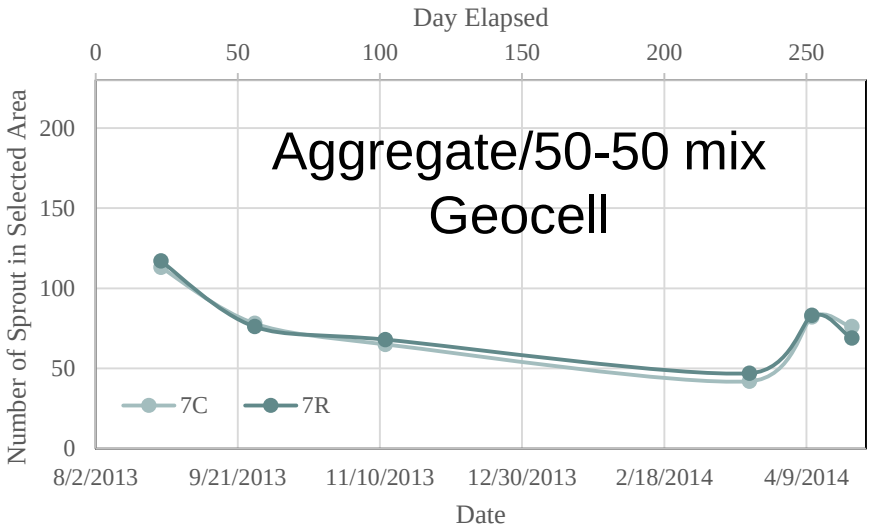


GRASS DENSITY









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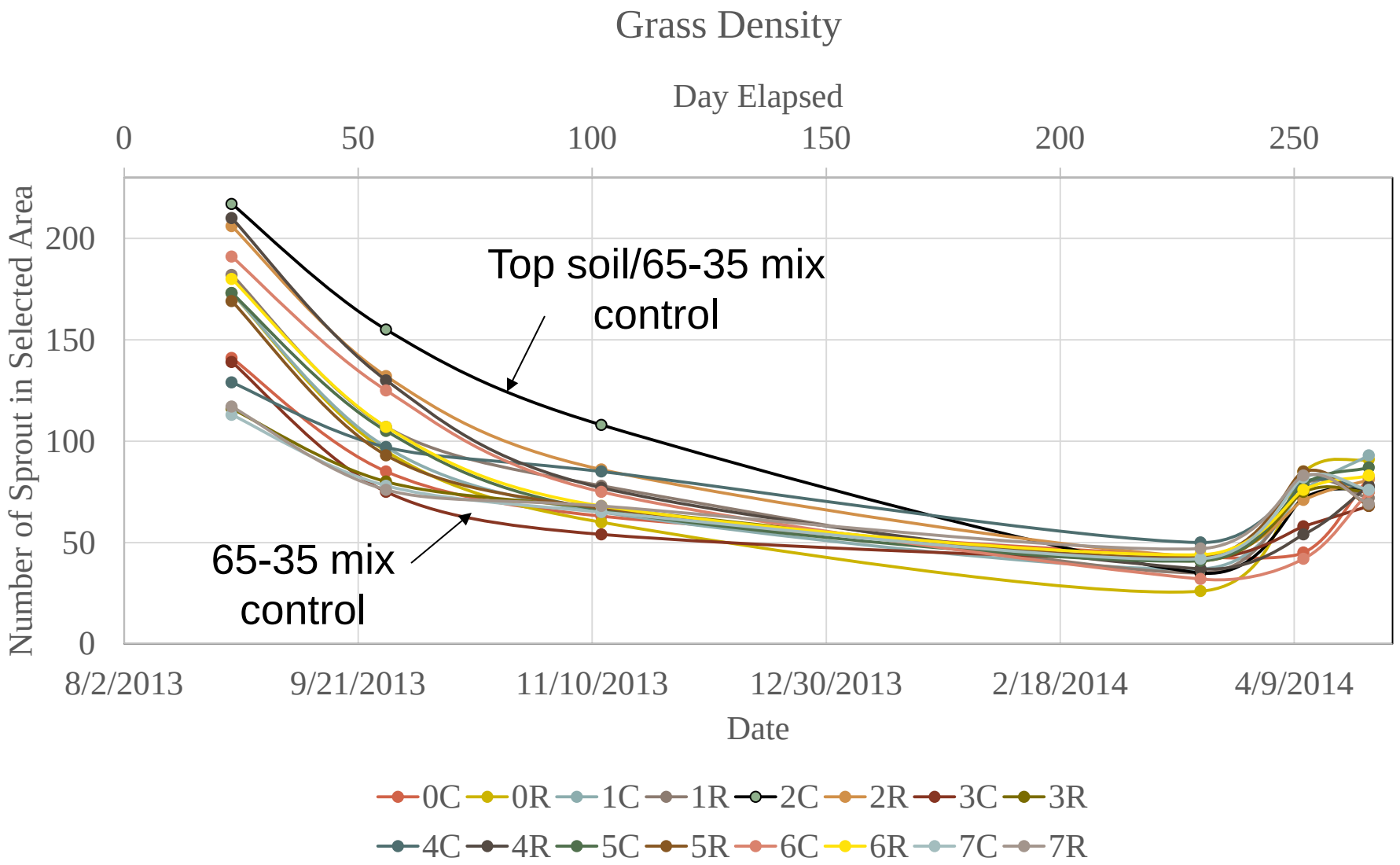
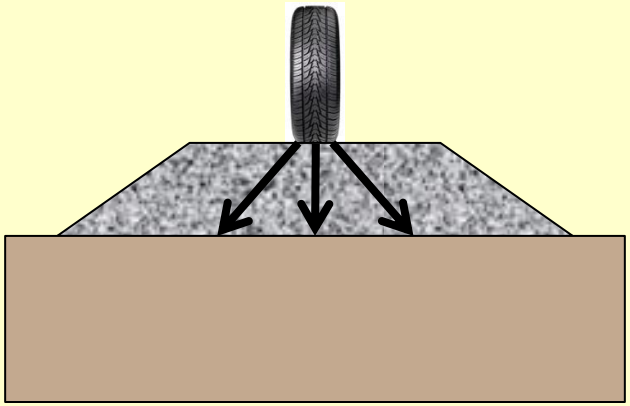


CONCLUDING REMARKS

- Geosynthetic erosion mats or geocells with vegetation minimize soil erosion.
- Geosynthetic reinforcement enhances surficial slope stability.
- Geosynthetic reinforcement does not affect vegetation growth.
- The surface soil does not have significant effect on the leaf blade length, but does affect the vegetation density.
- Geosynthetic reinforcement increases load capacities of unpaved roads
- Geosynthetic reinforcement is expected to provide a sustainable solution for vegetated slopes and green shoulders.



Thank you