MIXED HYDROLOGIC RECOVERY OF A DEGRADED MESQUITE RANGELAND

A Senior Scholars Thesis

by

MAXWELL CURTIS LUKENBACH

Submitted to the Office of Undergraduate Research
Texas A&M University
in partial fulfillment of the requirements for the designation as

UNDERGRADUATE RESEARCH SCHOLAR

April 2011

Major: Environmental Geosciences

MIXED HYDROLOGIC RECOVERY OF A DEGRADED MESQUITE RANGELAND

A Senior Scholars Thesis

by

MAXWELL CURTIS LUKENBACH

Submitted to the Office of Undergraduate Research
Texas A&M University
in partial fulfillment of the requirements for the designation as

UNDERGRADUATE RESEARCH SCHOLAR

Approved by:

Research Advisor: Bradford Wilcox
Director for Undergraduate Research: Sumana Datta

April 2011

Major: Environmental Geosciences

ABSTRACT

Mixed Hydrologic Recovery of a Degraded Mesquite Rangeland. (April 2011)

Maxwell Curtis Lukenbach
College of Geosciences
Texas A&M University

Research Advisor: Dr. Bradford Wilcox
Department of Ecosystem Science and Management

Land degradation and anthropogenic change is widespread on rangelands in Texas. Over the last 150 years, noticeable change has occurred as a direct result of agricultural practices and human activity. As novel ecosystems and permanently altered landscapes become more common, an understanding of these new environments becomes essential. The ability of rangelands to rebound from past degradation is a factor of interest and one this study attempts to quantify. How a localized hydrologic cycle responds to disturbance can be indicative of the health of an ecosystem. This study characterized the hydrology of a mesquite rangeland at Fort Hood, Texas and assessed the current hydrologic regime compared to similar rangeland sites. The site at Fort Hood is unique because it has undergone recent high intensity vehicular traffic and low intensity grazing. Additionally, the site was cultivated until Camp Hood was established in 1942. Presented within this paper are the results of a series of seven large-scale rainfall simulations, which quantified the hydrologic variables present at the Fort Hood site. Variables of interest included infiltration, runoff, and sediment loads. Key quantitative

findings of the study include: (1) Runoff values accounted for 28.7% - 64.9% of the total application of water applied to the plot. (2) Infiltration rates ranged from 15.1 mm/hr to 70.1 mm/hr at the site and (3) sediment loads ranged from 1.7 kg/ha to 4.2 kg/ha. These findings potentially indicate that the site has undergone a mixed recovery to its past hydrologic regime because erosion amounts are minimal, but infiltration rates are lower than comparable locations. This is important because it describes the ability of these landscapes to recover from past degradation.

ACKNOWLEDGMENTS

I would first like to recognize Dr. Bradford Wilcox for his time and commitment to me. I'm not sure that I could have been given a better mentor throughout this process and one that has such an extensive knowledge of the literature. I would also like to thank Dr. Clyde Munster; although you did not have the title of co-advisor, I felt as though you were one throughout this research project.

I would also like to thank all the others who helped me throughout this research project. Your time and commitment was incredible and I learned something new from each of you. So to Dr. Bill Fox, Jason McAlister, Jordan Grier, Patrick Haley, Raghavendra Jana, Matt Berg, Peter Min-Cheng Tu, Aaron Hoff, Cynthia Wright and anyone else I may have left out, thank you.

Such research projects are not possible without financial support. The Natural Resource Conservation provided financial support for this research and for this I am grateful. A special thanks, also, to those at Fort Hood who allowed us to use some of their inactive training sites for our research.

Finally, I would like to thank my family and friends who guided me through this process. I love each and every one of you and this would not have been possible without your support.

NOMENCLATURE

Anthropogenic	Of or related to the influence of human beings or their ancestors on natural objects.
Erosion	Is a gravity driven process that moves solids (sediment, soil, rock and other particles) in the natural environment or their source and deposits them elsewhere.
Hydrology	The study of the movement, distribution, and quality of water throughout Earth, and thus addresses both the hydrologic cycle and water resources.
Infiltration	The process by which water penetrates into soil from the ground surface.
Runoff	Is the water flow that occurs when soil is infiltrated to full capacity and excess water from rain, snowmelt, or other sources flows over the land. This is a major component of the hydrologic cycle.

TABLE OF CONTENTS

Page

LIST OF FIGURES

FIGURE Page

LIST OF TABLES

CHAPTER I

INTRODUCTION

Hydrologic and ecosystem processes recently merged into a new discipline called ecohydrology. This discipline describes the functional linkages between water and vegetation in the environment (Wilcox, 2010). A multitude of research is underway exploring the linkages between hydrology and vegetation. These studies provide a better understanding of ecosystem processes for incorporation into hydrologic models and natural resource management plans. As natural processes become better understood more researchers are interested in comparisons between natural environments and those altered by humans (Scanlon *et al.*, 2007). Evaluations of human impacts on the environment are quickly becoming, if they have not already become, a primary research topic of a diverse range of scientists. The need to quantify human impacts in ecosystems is increasingly important to both scientists and natural resource managers as they attempt to assess a changing world (Scanlon *et al.*, 2007).

Transformation on rangelands

Once changes are induced within the ecosystem, the hydrology of the landscape will change as a function of ecological processes (Scanlon *et al.*, 2007). Likewise, ecological

---

This thesis follows the style of *Hydrological Processes*.

processes are a function of a newly formed hydrologic regime (Scanlon *et al.*, 2007). A hydrologic regime can be defined as the spatial and temporal variations in the water cycle at a given location. The government, private sector, and researchers are interested in investigations that are able to better understand how changing watersheds will influence the water quality and water quantity of different regions (Scanlon *et al.*, 2007).

In Texas, a meaningful portion of the state is characterized as rangeland. Some of these rangelands can be classified as shrublands, which are areas where the dominate vegetation cover is brush and shrubs. Shrublands occupy a significant portion of the Earth's surface and are expanding their domain (Scanlon *et al.*, 2007). The influence of vegetation on watershed hydrology in rangelands is explored by an extensive community of researchers (Blackburn *et al.*, 1992; Blackburn *et al.*, 1990; Wilcox, 2010). Some efforts focus on quantifying spatial and temporal differences of vegetation in attempts to understand their influence on soil characteristics (Blackburn *et al.*, 1992; Blackburn *et al.*, 1990). Studies have shown that the spatial distribution of vegetation cover and type affect the soil characteristics in a given area (Blackburn *et al.*, 1992; Blackburn *et al.*, 1990). Because soil characteristics are influenced by vegetation, infiltration, and runoff processes, a reinforcing cycle is created that can improve or degrade the status of rangelands. As vegetation cover decreases, the balance between infiltration and runoff is shifted. Less vegetation cover exposes the underlying soil particles to additional detachment and transport; thus, when runoff occurs erosion will gradually become more severe over time (Brady and Weil, 2010). Figure 1 displays the negative reinforcing cycle that may occur when vegetation is altered by human practices.

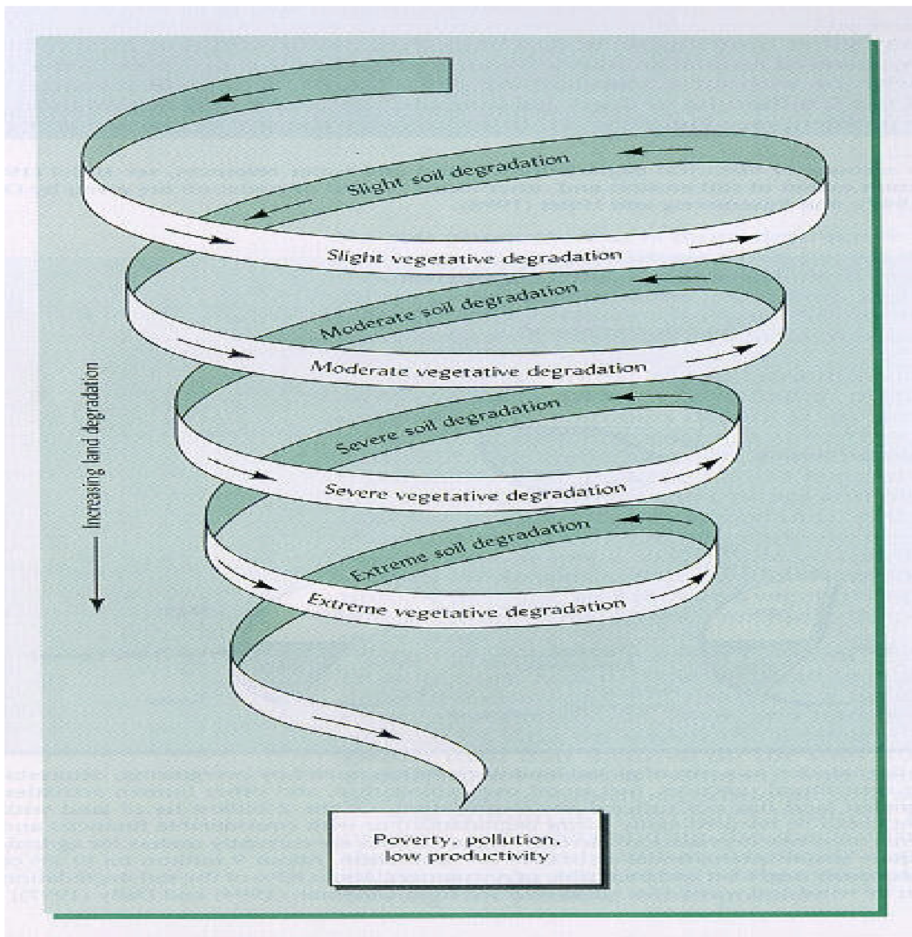

Figure 1. As degradation increases in a given landscape the consequences become more severe and lead to negative consequences. Source: (Brady and Weil, 2010).

Direct human transformations include various agricultural practices and indirectly include woody plant encroachment. Agricultural transformation began in the 1800s as ranchers expanded their grazing domain into the Southwest and Texas (Wilcox *et al.*, 2008a). Grazing continues today on a significant amount of Texas rangelands and is of economic and environmental importance. From a hydrologic perspective, heavily grazed rangelands tend to have lower infiltration rates and higher erosion rates than non-grazed and less intensely grazed rangelands (Wood and Blackburn, 1981a; Wood and Blackburn, 1981b). Expansion of agriculture has also brought about the widespread use of mechanical farm equipment and vehicles. The effect of wheel traffic and vehicle usage has also been shown to degrade and alter hydrologic regimes leading to lower infiltration rates and higher erosion amounts (Li *et al.*, 2001). Woody plant encroachment, which is the conversion of grasslands to woodlands, is another ecological transformation that alters the water cycle (Asner *et al.*, 2003). In many cases, occurrences of woody plant encroachment are an unintended result of anthropogenic effects such as overgrazing and the reduction of natural fire events (Van Auken, 2000). Unlike hydrologic impacts brought about by grazing, the hydrologic impacts of woody plant encroachment are debatable and research continues to uncover the role vegetation cover change plays in rangeland hydrology (Dasgupta *et al.*, 2006; Gregory *et al.*, 2009; Taucer *et al.*, 2008; Wilcox *et al.*, 2008b). Research in rangeland hydrology centralizes an understanding of where water travels in response to vegetation cover. Conclusions of these studies convey the importance that the spatial distribution of vegetation has on the movement of water through the environment (Dasgupta *et al.*, 2006; Gregory *et al.*, 2009; Taucer *et al.*, 2008; Wilcox *et al.*, 2008b).

Resource and rangeland management strategies are evaluated through scientific field work (Wilcox *et al.*, 2008b). A common management strategy used and consequently evaluated in rangelands is shrub removal. This effort focuses on reducing woody plant cover in order to increase streamflow and recharge to aquifers. Shrub removal has been the subject of much controversy, as substantial resources have already been poured into such programs. As of 2006, forty million dollars had been spent by the state of Texas on shrub removal programs (Taucer *et al.*, 2008). Investigations and evaluations found that in humid regions shrub removal may be a reasonable way to increase yields; however, in some areas shrub removal had little effect on water yields (Wilcox, 2002). The optimal approach is to individually examine the ecohydrology of each site because there is not a universally applicable management strategy (Wilcox, 2002). The opportunity for increased water yields will be different at each location depending on climate and ecosystem distinctiveness (Wilcox, 2010).

Rainfall simulation

In order to better understand hydrologic processes occurring on rangelands, research has employed the use of rainfall simulation. Rainfall simulation is a means to assess hydrologic processes by having a known input value or controlled precipitation variable. By recording the application amount on a study plot, estimations of runoff and infiltration are made. Past studies have typically utilized small scale rainfall simulation on minute plots; usually less than or equal to one meter squared (Wilcox *et al.*, 1986). However, as rainfall simulation technology has advanced, larger simulations are able to yield greater results for hillslope scales (Gregory *et al.*, 2009). Interactions occurring at larger scales may vary significantly from those at smaller scales (Moreno-de las Heras *et al.*, 2010). In hydrology this is especially important because larger assessments allow for a more expansive understanding of the water cycle (Moreno-de las Heras *et al.*, 2010). Examinations of hydrologic regimes employing large-scale rainfall simulation have yielded better portrayals of the hydrologic processes transpiring in rangelands (Gregory *et al.*, 2009; Taucer *et al.*, 2008; Wilcox *et al.*, 2008b). Large-scale rainfall simulation has also been used to analyze range management strategies by examining sites before and after implementation (Taucer *et al.*, 2008; Wilcox *et al.*, 2008b). The evaluation of management strategies using rainfall simulation continues to be useful when involved parties are concerned about changes taking place in the hydrologic cycle of a specific area.

Study objective ..

The purpose of this study is to utilize large-scale rainfall simulation to provide an analysis of the hydrologic processes occurring in a mesquite rangeland at Fort Hood, Texas. The data presented in this work are the first in a series of large-scale rainfall simulations occurring at Fort Hood. A major use of this information will be for comparisons between study sites, but until additional data are collected this cannot be done; thus, the primary goals of this research are to provide a detailed hydrologic description of the current study site, to illustrate the value of large-scale rainfall simulation, and to quantify the impact that past degradation continues to have on current hydrologic processes.

The initial study site is significant because its history has encompassed a wide array of human activities. These activities have included cultivation, livestock grazing, and, most recently, military traffic. These practices alter soil characteristics and transform vegetation cover. Military traffic does not occur consistently across the site, but rather on a rotational basis. The initial study site has substantial vegetation cover and appears to be recovered from past degradation. As a result, the initial study site is useful in comparisons to severely degraded sites. Separate rainfall simulations on degraded sites, shrub-controlled sites, and restored sites are planned at Fort Hood in the near future. Once data are available for each site, comparisons can be drawn and management techniques can be assessed.

Variables of interest in this study include sediment loads, infiltration, and runoff. Erosion and sedimentation processes are of interest at this site because of their role as a possible pollutant in surface water bodies. Military traffic and training likely alter the amount of erosion that occurs. The study site has not recently undergone intensive use and was unlikely to have significant erosion; however, past degradation could still have an effect at the site. Infiltration and runoff data are valuable because they assist in assessing the hydrologic characteristics of the site. Both can be used to judge the recovery of the site from a degraded state. In addition, runoff and infiltration measurements provide further knowledge about the ecohydrology of mesquite rangelands.

CHAPTER II

METHODS

Site description

The study site is located at the Fort Hood military reservation near Copperas Cove, Texas (31º14’51.37”, 97º52’06.27”) (See Figure 2). Fort Hood, located in Central Texas, is divided between both Bell County and Coryell County. Fort Hood was established in 1942 when Camp Hood was set up as a training area during World War II (Soil Survey Staff). In 1951 the military reservation gained permanent status under the name of Fort Hood and has remained under military management since (Soil Survey Staff). Prior to the presence of a military installation, the study site was farmed and cultivated (See Figure 3). While farming and cultivation has ceased, agricultural activity continues through a grazing lease that was granted to ranchers, allowing livestock to occupy inactive training sites at Fort Hood (Soil Survey Staff).

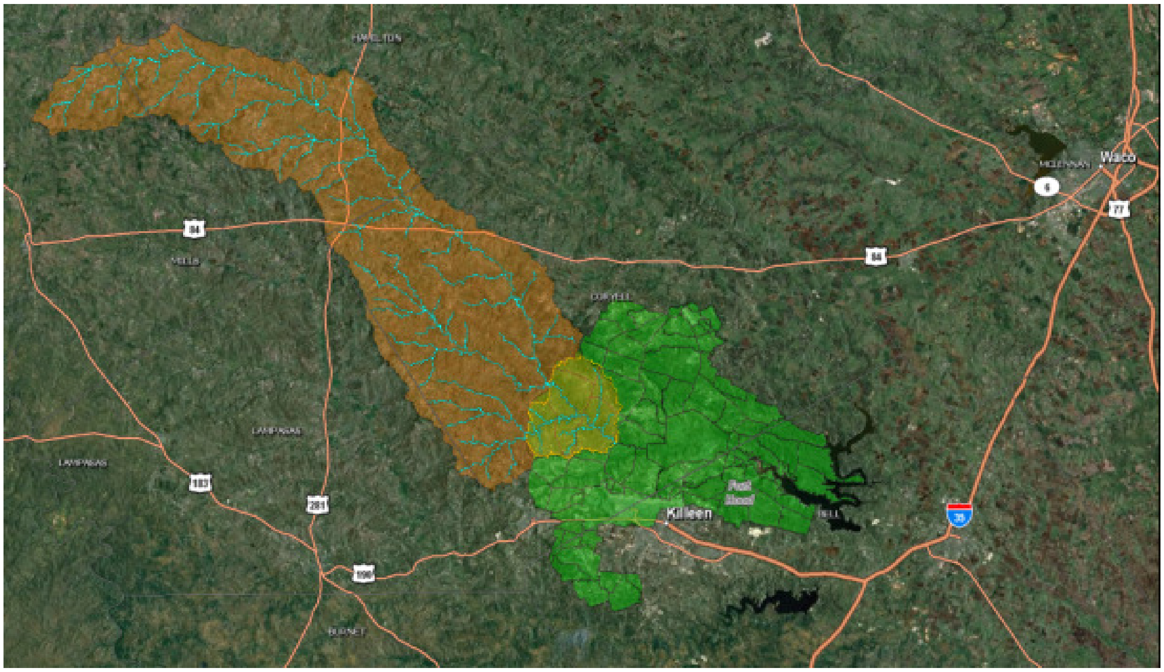

Figure 2. The rainfall simulations took place at Fort Hood, Texas. A map of Fort Hood (green) and a corresponding watershed (orange) are shown above.

Figure 3. The past land use at Fort Hood is displayed above. Above is an aerial photograph displaying the rangeland conditions of the study area 1939. The current study site lies within a once cultivated field.

The climate at Fort Hood is variable because it lies at the border of a humid subtropical region to the east and a semi-arid zone to the west (Soil Survey Staff). The long term average annual rainfall at Fort Hood is approximately 34 inches; however, this fluctuates from year to year (Soil Survey Staff).. Temperatures are also quite variable and can range from 32ºF in the winter to around 100ºF in the summer (Soil Survey Staff). The diverse climate at this location results in periods of extensive drought and prolonged wet periods that can regularly last from 6 – 12 months (Soil Survey Staff).

Research plots

An above canopy rainfall simulator was installed to analyze the ecohydrology at a Fort Hood study site in October of 2010. The plot was separated from the surrounding environment by a galvanized sheet metal border. The border allowed hydrologic measurements within the plot to be uninfluenced by hydrologic activity outside of the plot. A 14 meter long side was orientated along the hillslope (1% – 3%), while a 7 meter long side was orientated perpendicular to the hillslope, allowing for easier runoff capture. There was extensive vegetation on the plot consisting of mesquite brush and various grasses. Vegetation cover on the plot consisted of approximately 29 mesquite shrubs as well as a substantial amount of underlying grasses and brush.

Data was collected for seven different rainfall simulation trials. Each trial yielded precipitation data, runoff data, and sediment load data. Infiltration was estimated by finding the difference between precipitation and runoff.

Geology and soils

The primary geologic constituents of the Fort Hood study site are from the Lower Cretaceous Age with the remaining geologic components forming from alluvial deposits and flood plains of the Quaternary Age (Soil Survey Staff). Eroded sedimentary rock of the Cretaceous strata along with deposition of unconsolidated materials has resulted in the current landscape found at Fort Hood (Soil Survey Staff). The current landscape is typically referred to as the Blacklands Prairie because of the dark soils that are found in the region. The soils at the study site are classified under the Lewisville Series, specifically Lewisville clay loam. These soils tend to be deep (approximately 170 centimeters deep), high in clay content, formed from alluvium, and well-drained (Soil Survey Staff). Runoff is classified as medium for this soil series and the available water capacity of the soil is high due to the high clay content (Soil Survey Staff).

Vegetation cover

Due to human and environmental influences, the vegetation presiding at Fort Hood varies. Generally, there are four categories of vegetative communities: coniferous forest and scrub, deciduous forest and scrub, mixed forest and scrub, and grasslands (Soil Survey Staff). The type of vegetation occurring in each zone is often highly disturbed by military training exercises (Soil Survey Staff). Incidentally, unintentional wildfires occur that suppress and alter surrounding vegetation (Soil Survey Staff). Vehicle usage and other training practices are also common, which often degrade and reduce vegetation cover. The study site analyzed in this research has not been disturbed for several years and is listed as an inactive training zone. The enclosed area consists of roughly 29 small, medium, and large sized mesquite shrubs as well as various grasses and brush. These grasses and brush include little bluestem (*Schizachyrium scoparium*), Texas wintergrass (*Nassella leucotricha*), broomweeds (*Amphiachyris* sp.), ragweed (*Ambrosia* *artemisiifolia*), three-awn (*Aristida* sp.), and snow-on-the-prairie (*Euphorbia bicolor*). The brush and grass cover is weakly developed and is not difficult to clear in order to gain access to the soil surface.

Rainfall simulator

The rainfall simulator used in this research was developed by Dr. Clyde Munster at Texas A&M University. It is fully explained in Munster *et al.* 2006. The rainfall simulator applied water to the plot through a system of six telescoping masts topped with irrigation nozzles having the ability to extend to a maximum height of 11 meters (see Figure 4).

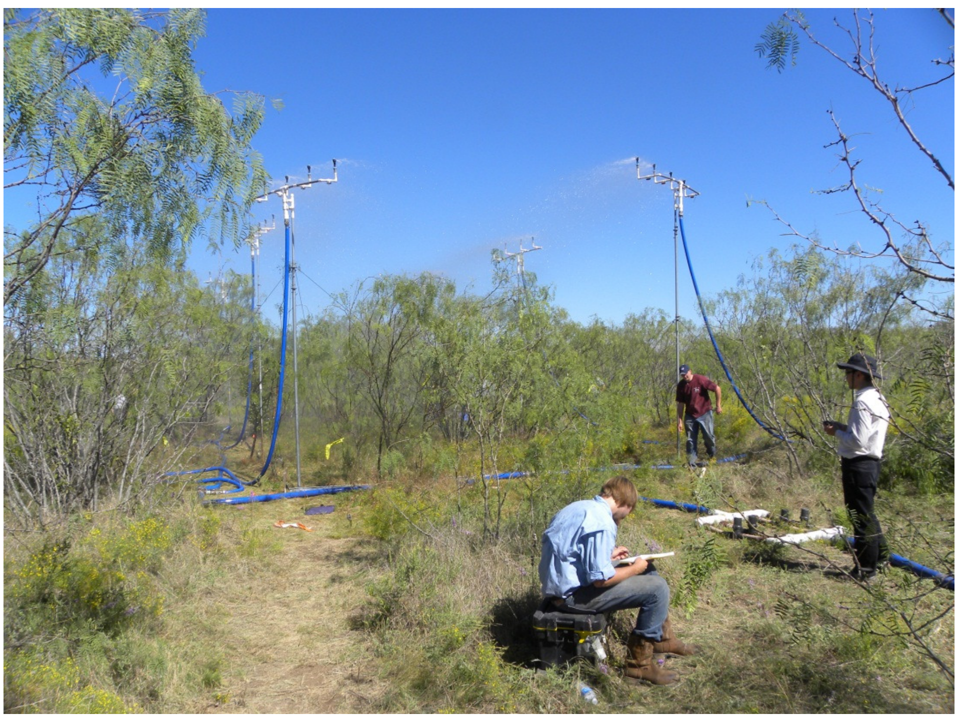

Figure 4. A picture taken of the rainfall simulator in action placed over a mesquite canopy at Fort Hood, Texas.

The masts were located around the plot to eliminate their hydrologic influence within the plot. Connected to the masts were manifolds equipped with sprinklers that dispersed water over the plot. The rate of water coming out of the sprinklers was controlled by a fitting in each sprinkler (Munster *et al.*, 2006). In addition, each individual sprinkler contained a valve that allowed for them to be separately switched on or off when desired (Munster *et al.*, 2006). The rainfall simulator applied water at rates ranging from roughly 1.9 cm per hour to 10 cm per hour. This rate was controlled by adjusting the sprinkler valves on and off and adjusting the pressure fittings. The median raindrop size was variable during the rainfall simulation, but was representative of natural rainfall events (Munster *et al.*, 2006). Water was moved to the rainfall simulator using a series of lay-flat hoses and pumps (Munster *et al.*, 2006). These pumps moved water from storage tanks, which had a capacity of approximately 7500 gallons, into the manifolds for application onto the plot (Munster *et al.*, 2006).

Seven rainfall simulation trials occurred over the course of three days. There were two rainfall simulations on the first day, three on the second day, and two on the third day. The first trial utilized two sprinkler heads per mast and lasted for sixty minutes. It was intended to be an initial analysis of how much time and water should be dedicated to each rainfall simulation. Trials 2, 4, and 6 were replicates of one another that utilized only one sprinkler head per mast. The duration of these trials was approximately 45 minutes. Trials 3 and 5 were also replicates of one another; each utilized two sprinkler heads per mast for 30 minutes. Trial 7 was intended to be a replicate of trials 3 and 5, but due to a pumping issue it was shut down early after only 15.5 minutes had elapsed.

Hydrologic measurements

The amount of rainfall on the plot was measured using 120 plastic precipitation gauges with a capacity of 140 millimeters. The precipitation gauges were organized in a one meter grid throughout the plot in order to sufficiently cover the study area. At the end of each rainfall simulation the precipitation gauges were read by entering the plot and manually reading the measurement. Runoff from the plot was measured using a 6 inch H-flume. The depth of water in the flume was measured, which was then converted into a runoff volume at a later time using a known relationship between the water depth in the flume and the volume of runoff. The depth of the water in the flume was measured both manually with a tape measure and electronically with an ISCO model 3200 bubble flow meter. Usually only one of these methods was employed, but at times both were used to better validate the runoff readings. Runoff measurements were intended to be taken at three minute intervals; however, not all of the intervals were of this desired length. For each trial runoff data was integrated in order to calculate the total volume of runoff. Measurements of runoff and precipitation allowed for the computation of infiltration. Infiltration is calculated by subtracting the runoff from the average precipitation across the plot.

During the trials, sediment load data were collected using sampling bottles. Each of these measurements was taken at approximately five minute intervals. The bottles were stored and sorted by trial and then placed in a chamber for further analysis at Blacklands Research Laboratory. After the concentration of sediment was evaluated, the data were sent back to the Wilcox Watershed and Ecohydrology Lab for further analysis.

Comparisons were also made between natural rainfall events and the rainfall simulation trials. Following the rainfall simulation trials the plot was left undisturbed and fitted with a Parshall Throat flume. The galvanized sheet metal barrier was also left intact. The ISCO model 3200 bubble flow meter measured the depth of water in the flume of the natural events at five minute intervals. Precipitation measurements were taken every fifteen minutes by a rain gauge set up on top of the equipment shelter. One natural rainfall event triggered the runoff meter and was found to be large enough for comparison. Infiltration was once again calculated by subtracting runoff from the measured precipitation value.

CHAPTER III

RESULTS

Precipitation measurements

Rainfall applied for the seven trails ranged from 19 mm – 99.1 mm. The large discrepancy was a result of the varying length of the rainfall simulations, which ranged from 15.5 minutes to 60 minutes. Precipitation amounts for trials 1 – 7 are displayed in Table I. Precipitation graphics were constructed to display the distribution of rainfall across the research plot for each individual trial. Rainfall data allowed for the production of graphical interpolations across the entire plot (See Figures 5-11). Histograms were also produced for the seven trails in order to further exhibit the distribution of rainfall across the plot (See Figure 12).

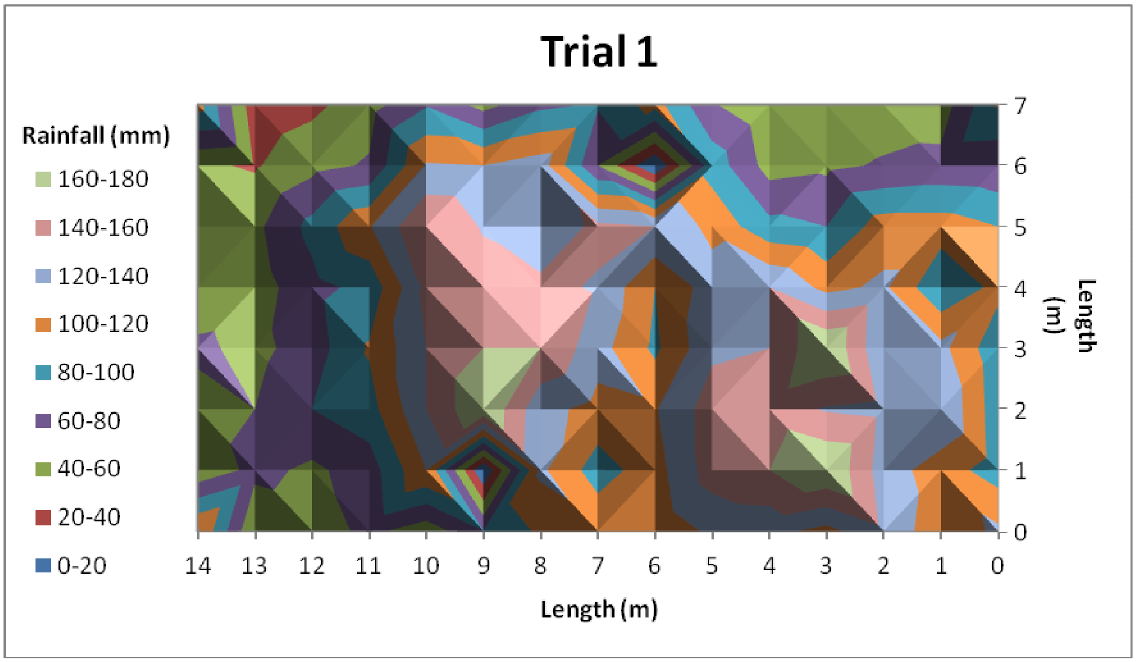

Figure 5. Graphic illustrates the distribution of rainfall across the plot for trial 1.

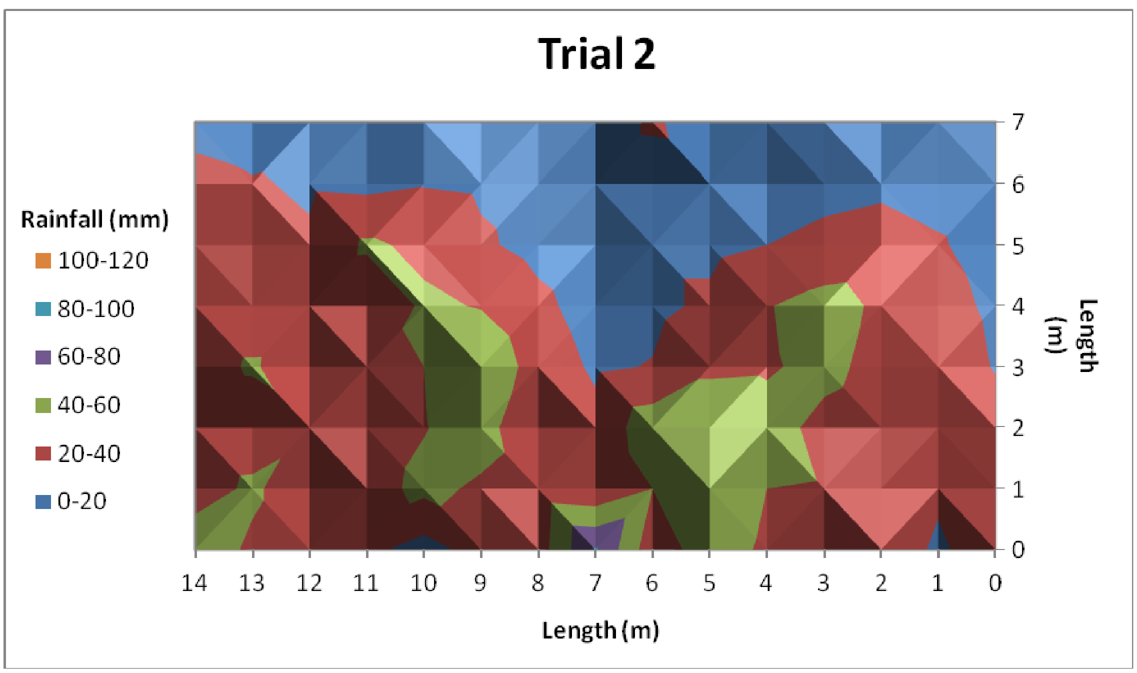

Figure 6. Graphic illustrates the distribution of rainfall across the plot for trial 2.

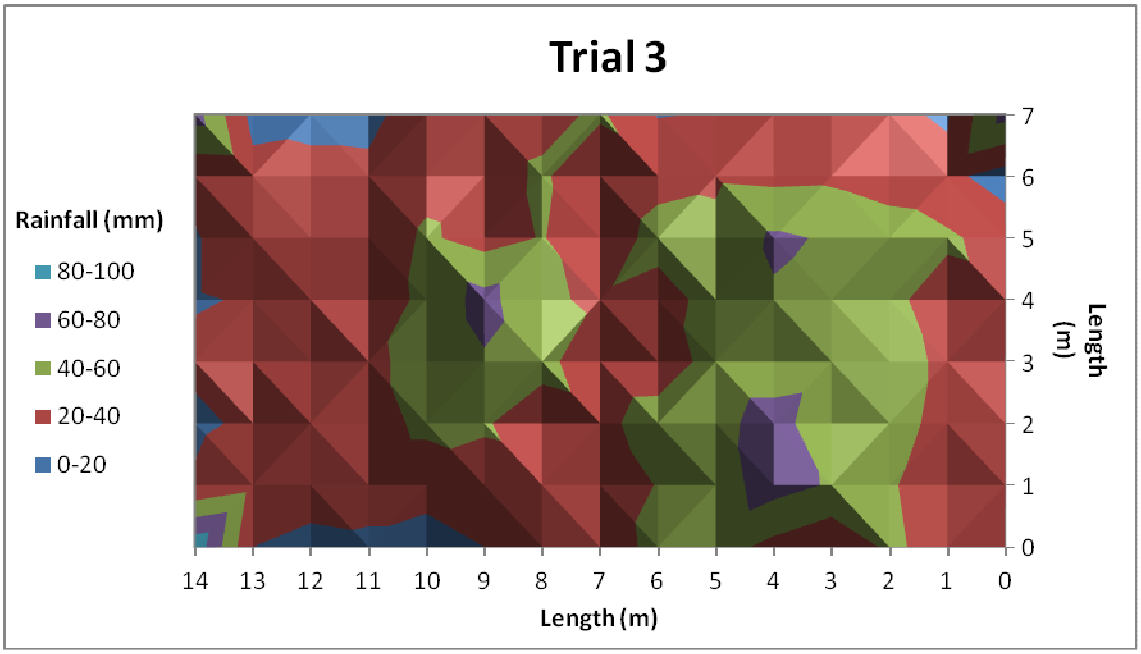

Figure 7. Graphic illustrates the distribution of rainfall across the plot for trial 3.

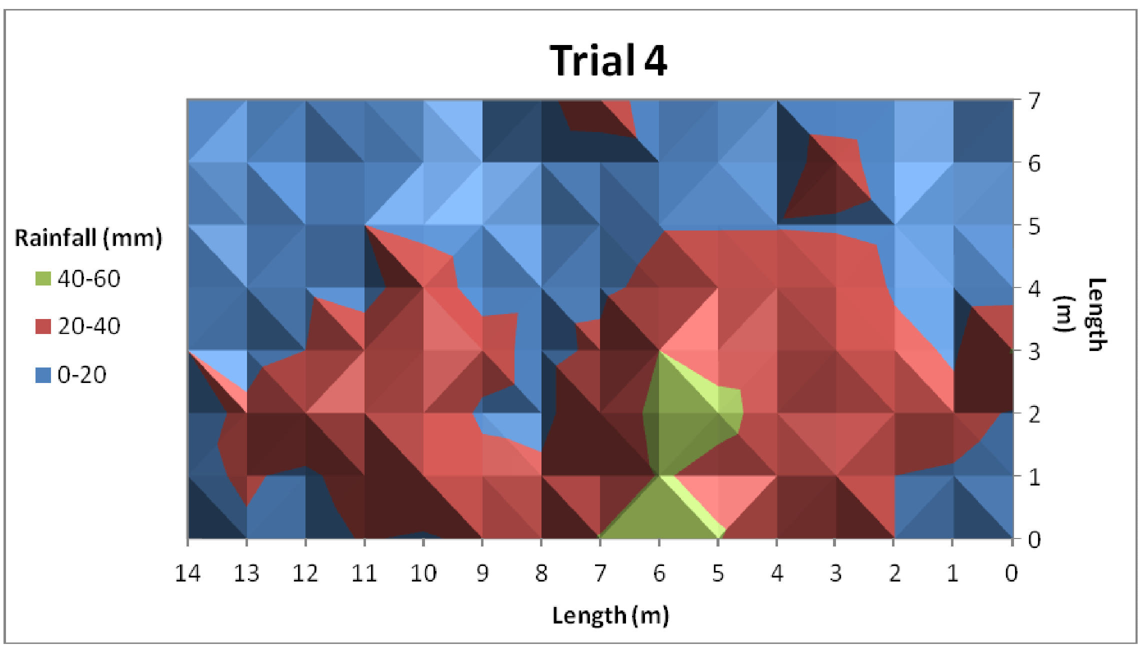

Figure 8. Graphic illustrates the distribution of rainfall across the plot for trial 4.

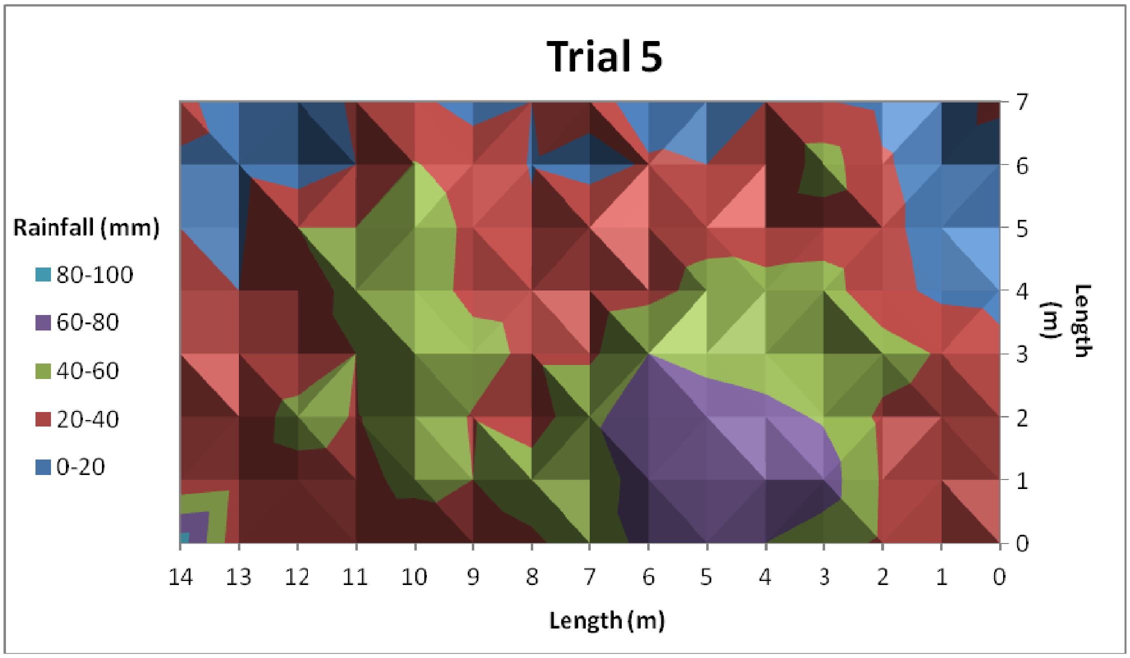

Figure 9. Graphic illustrates the distribution of rainfall across the plot for trial 5.

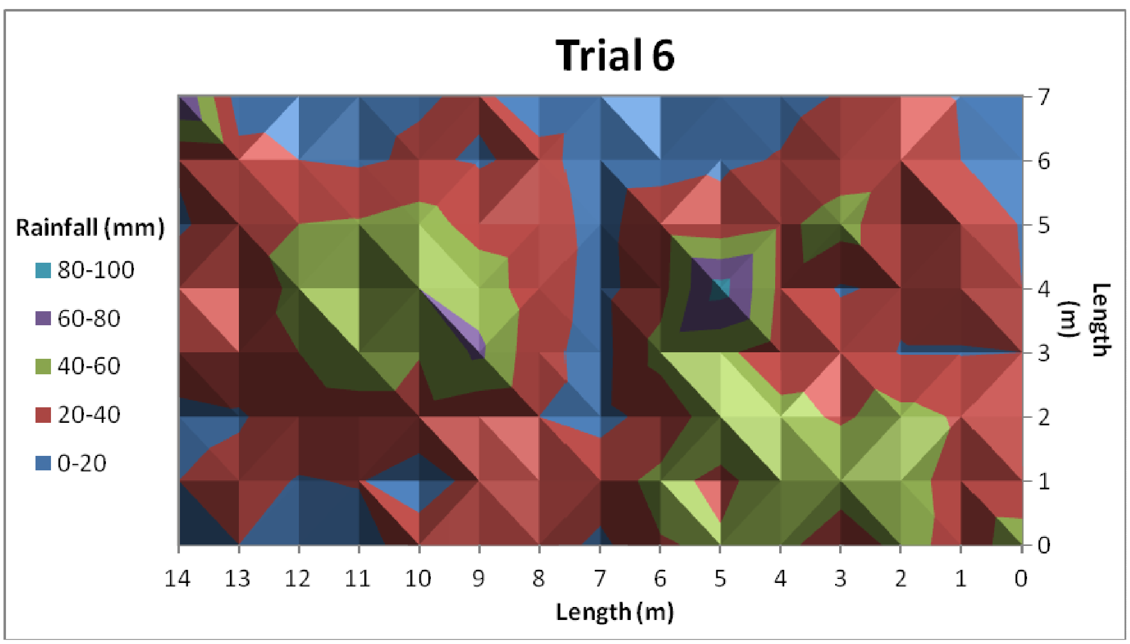

Figure 10. Graphic illustrates the distribution of rainfall across the plot for trial 6.

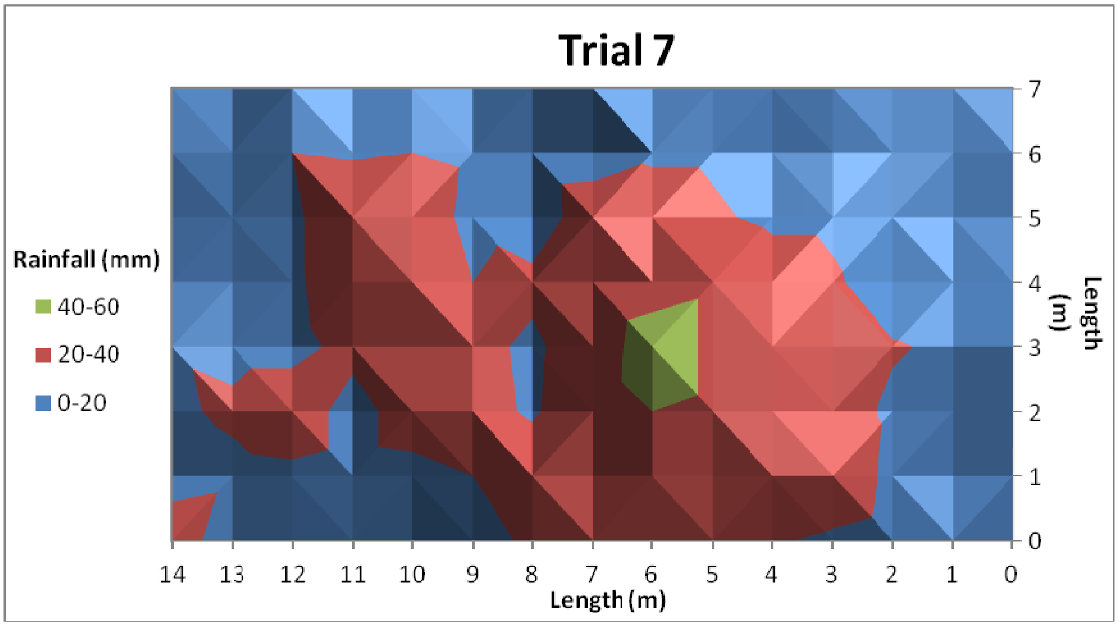

Figure 11. Graphic illustrates the distribution of rainfall across the plot for trial 7.

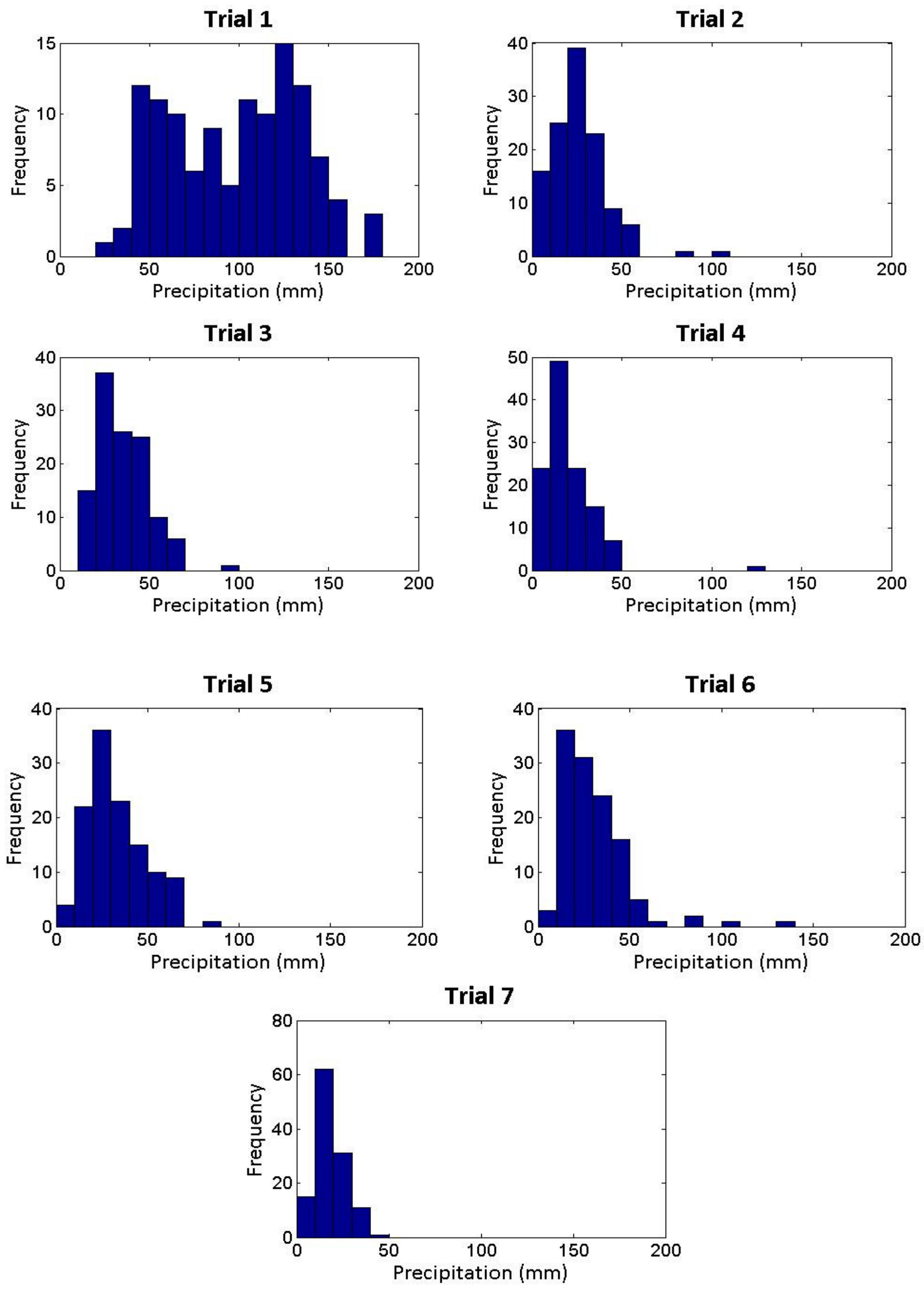

Figure 12. A series of histograms produced from precipitation data that display rainfall distribution across the experimental plot. Rainfall measurements were binned into 10 millimeter increments.

Runoff measurements

Runoff values are listed in Table I for trials 1 - 7. Runoff as a percentage of the total application is also listed in Table I. A significant amount of runoff occurred during each rainfall simulation and accounted for 28.7% to 64.9% of the total rainfall applied. As expected, runoff increased throughout the series of simulations as antecedent moisture conditions became more saturated. More than one rainfall simulation occurred on each research day resulting in increased runoff throughout the day. Hydrographs provided below in Figure 13 show that the runoff dropped off sharply after rainfall ended. Generally, runoff peaked when rainfall stopped or shortly thereafter.

Table I. A data summary from the rainfall simulations occurring from 10/15/2010 – 10/17/2010 is provided above. Trials 2, 4, and 6 were replicates of each other as were trials 3 and 5. In addition to the rainfall simulations, a natural event was measured and its data is displayed above. Tr stands for the time when runoff began.

Trial	Total Applied (mm)	Tr	Runoff (mm)	Runoff %	Infiltration (mm)	Sediment (kg/ha)	Length of Run (min)	Date of Run
1	99.1	38	28.5	28.7	70.6	2.5	60	10/15/2010
2	26.8	10	11.2	41.6	15.6	1.7	47	10/15/2010
3	34.9	14	9.8	27.9	25.1	3.2	30	10/16/2010
4	19.9	4	8.1	40.4	11.8	N/A	45	10/16/2010
5	33.5	3	21.8	64.9	11.7	N/A	30	10/16/2010
6	30.1	21	16.7	40.4	13.4	4.2	45	10/17/2010
7	19.1	3	10.9	57.4	8.2	N/A	15.5	10/17/2010
Natural	42.4	35	22.6	53.3	19.8	N/A	480	01/09/2011

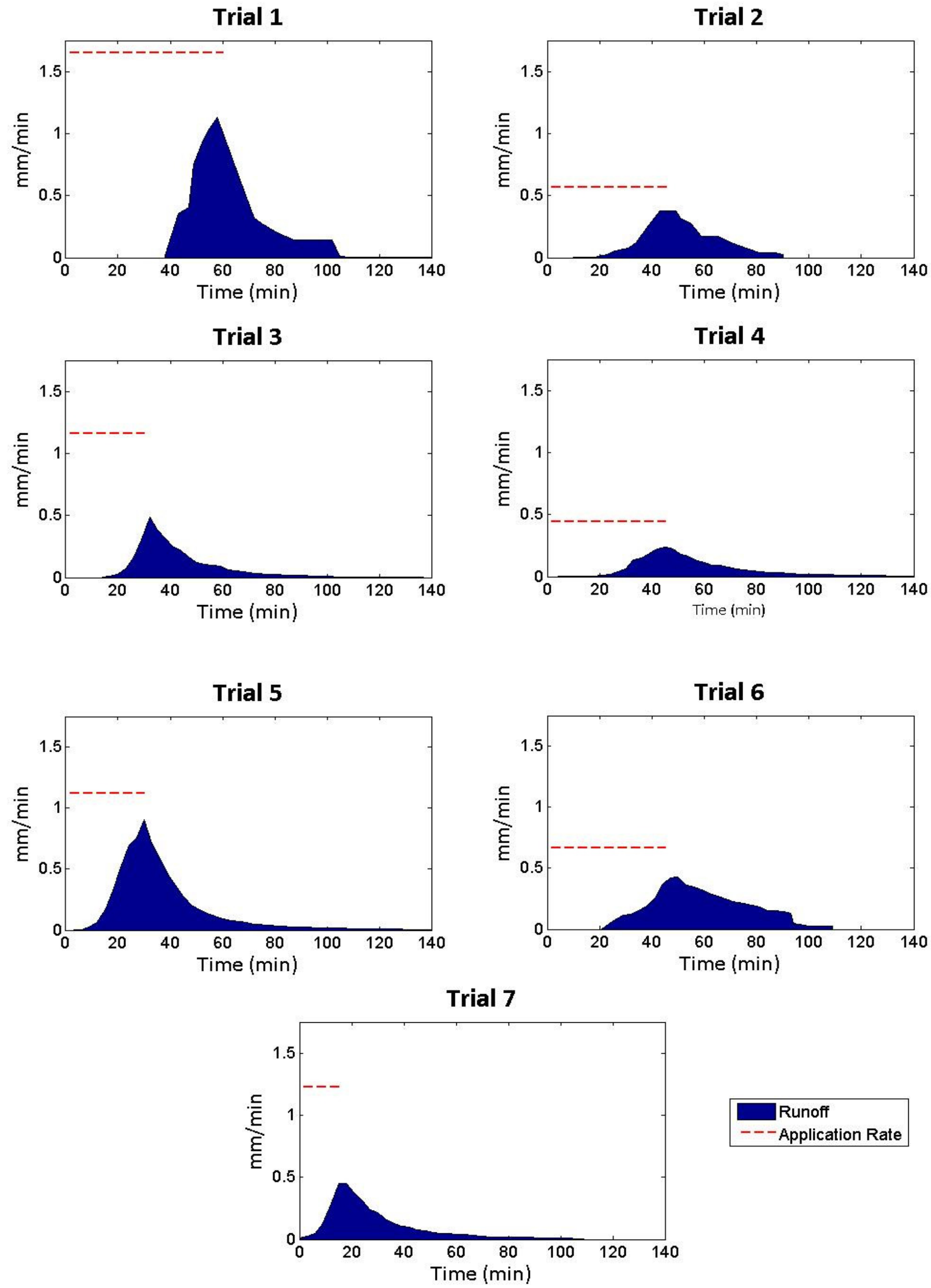

Figure 13. Hydrographs above are for trials 1-7 display runoff distribution as a function of time. The area under the curve is considered runoff and the dashed red line signifies the application rate. The dashed red line ends once rainfall ceased on the plot.

Infiltration estimations

Infiltration was calculated as the difference between precipitation and runoff. Infiltration was highest at the start of the rainfall event and receded as time passed and runoff intensified. Figure 14 displays infiltration curves for the seven trials. Infiltration decreased until rainfall application stopped and then recovered slowly as runoff leveled off. During most of the trials it appears as though the infiltration equilibrium rate was not reached; however, in trials 2 and 4 infiltration rates nearly reach a constant at the end their respective the runs.

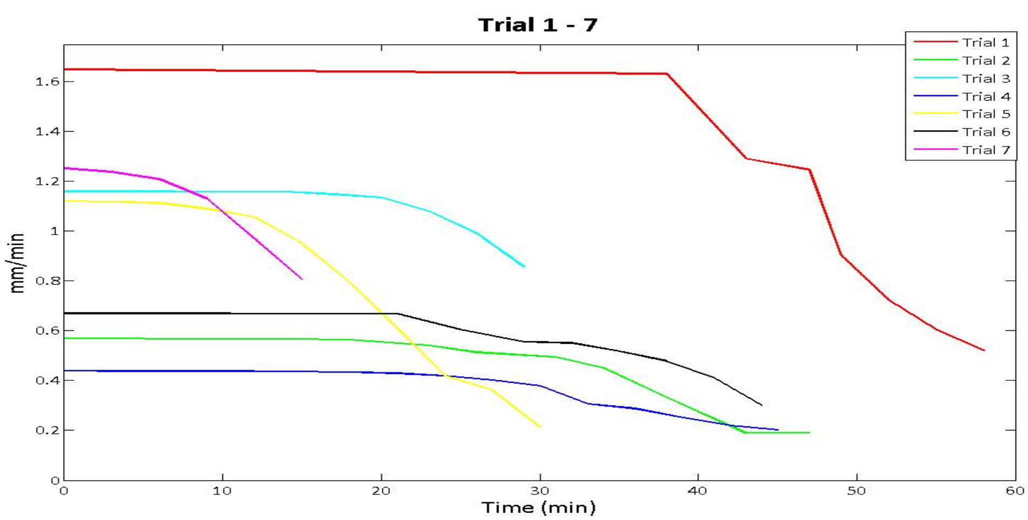

Figure 14. Infiltration curves were plotted for each trial above. Infiltration was only calculated during rainfall because infiltration is the difference between precipitation and runoff. In trials 2 and 4 the infiltration rate may have reached equilibrium. In the other trials the infiltration rate was still decreasing when rainfall stopped.

Sediment load measurements

Sediment loads were recorded for all of the trials, but only data for four of the trials were processed. Sediment loads were low and values ranged from 1.7 – 4.2 kg/ha for each of the four trials. Specifics are displayed in Table I above. Additionally, a plot of sediment concentration as a function of time was created (See Figure 15). Sample concentrations taken at earlier runoff times were generally higher than those taken at later runoff times.

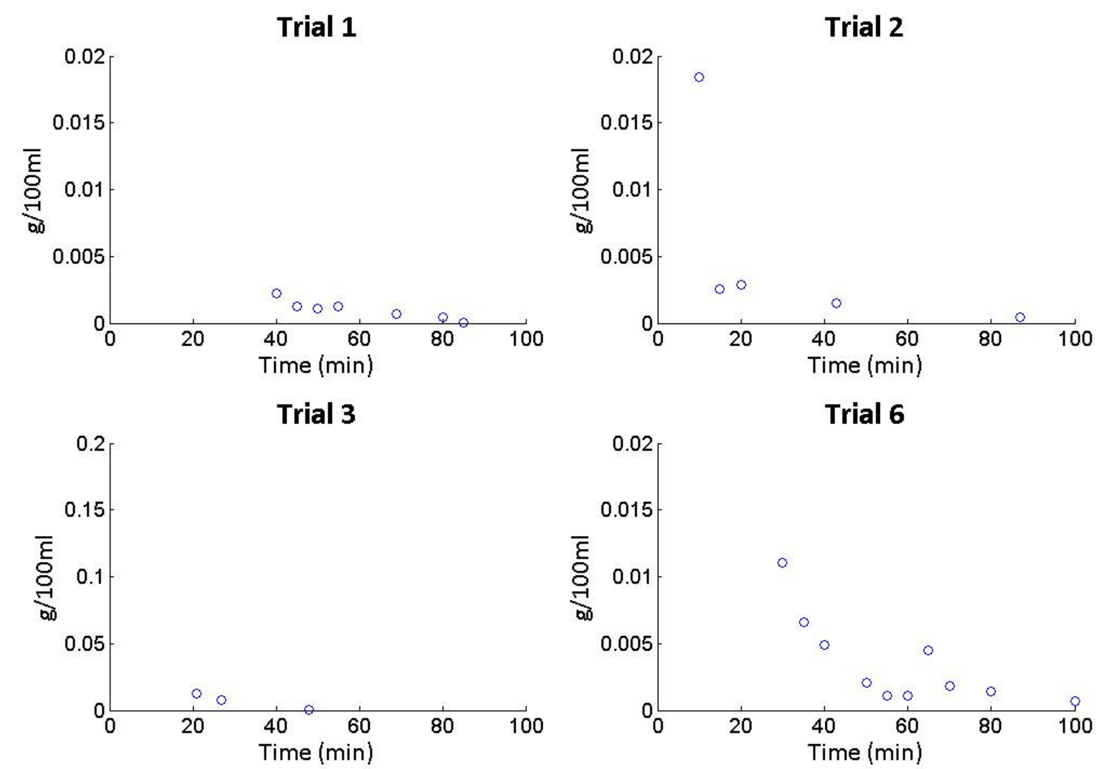

Figure 15. Sediment concentrations from runoff samples were charted for trials 1, 2, 3, and 6. Higher values tend to occur in earlier samples, while lower values tend to occur in the later samples.

Natural rainfall events

One measurable natural rainfall event occurred on the plot after devices were in place to measure precipitation and runoff. This event occurred on January 9th, 2011. Over the course of the entire event precipitation was measured to be 42.4 millimeters. Approximately 22.6 millimeters of the 42.4 millimeters received on the plot occurred as runoff. The rest was assumed to infiltrate into the soil (see Table I for additional values).

CHAPTER IV

DISCUSSION AND CONCLUSIONS

The studies at Fort Hood continue to provide evidence and support for large-scale rainfall simulation as a means to assess the hydrologic controls on rangelands. Past large-scale rainfall simulations have successfully mapped the hydrology of karst landscapes and quantified the extent that vegetation controls water movement in the environment (Gregory *et al.*, 2009; Taucer *et al.*, 2008; Wilcox *et al.*, 2008b). This study deviated from recent large scale rainfall simulations in that it was carried out on a mesquite rangeland that has undergone noticeable anthropogenic alterations. The characterization provided above in the figures and tables allow for the formation of unique hypotheses. These hypotheses and questions investigate (1) the quantification of degradation occurring on rangelands (2) the resiliency of a landscape to rebound to a past hydrologic regime.

Infiltration and sediment load analysis

Infiltration rates and runoff rates are excellent indicators of the hydrologic response of a rangeland to disturbance. Past studies of rangelands have used infiltration rates as a variable to indicate the effect that grazing has on rangelands (Wood and Blackburn, 1981a). These studies utilized drip infiltrometers or small-scale rainfall simulators to measure infiltration rates of study sites (Knight *et al.*, 1983; Wood and Blackburn, 1981a). In most instances, more intense grazing practices decreased the infiltration rates at a given site (Wood and Blackburn, 1981a). Because infiltration and runoff directly complement one another, it is assumed that water which traditionally infiltrated the soil occurred as runoff after degradation occurred. The following discussion outlines related research, all of which took place in mesquite canopy plots.

Brock *et al.* 1982 examined infiltration rates and sediment loads occurring in a honey mesquite rangeland in the Rolling Plains of Texas. The study analyzed the effect that different shrub control treatments had on infiltration rates and erosion amounts. Soils at the site were mostly clay loam textured and infiltration rates were measured using a mobile drip infiltrometer. This study found that the infiltration in a natural mesquite shrubland ranged from 96 mm/hr to 112 mm/hr and sediment loads ranged from 19 kg/ha to 80 kg/ha (Brock *et al.*, 1982).

Research carried out in Knight *et al.* 1983 occurred at the Texas Experiment Ranch (Knight *et al.*, 1983). Like the previously mentioned study, data gathered assessed the effect that various shrub control practices had on infiltration rates and sediment loads. Infiltration rates ranged from 113 mm/hr to 128 mm/hr and sediment loads ranged from 1160 kg/ha to 2335 kg/ha. Research on this site was performed in a running mesquite rangeland between Freer and Cotulla, Texas. Soils on the site were predominantly clay loam textured and infiltration rates were measured using a mobile drip infiltrometer on small plots (.5m^2) (Knight *et al.*, 1983).

In separate studies by Blackburn and Wood, investigations were carried out assessing the impact that different grazing strategies had on infiltration rates and sediment loss (Wood and Blackburn, 1981a; Wood and Blackburn, 1981b). Infiltration rates ranged from 128 mm/hr to 172mm/hr and sediment loads ranged from 2.3 kg/ha to 22.6 kg/ha. Research on this site occurred in a honey mesquite and lotebrush rangeland at the Texas Experimental Ranch in the Rolling Plains of Texas. Soils at the site were primarily clay loam and clay textured and infiltration rates were measured using a mobile drip infiltrometer (Wood and Blackburn, 1981a; Wood and Blackburn, 1981b).

These three studies offer strong comparisons to the current Fort Hood site because each involves mesquite canopies, clayey soils, and an anthropogenic component. Figures 16 and 17 below provide the Fort Hood study sites' infiltration and sediment loads compared to those studied at similar sites in Texas.

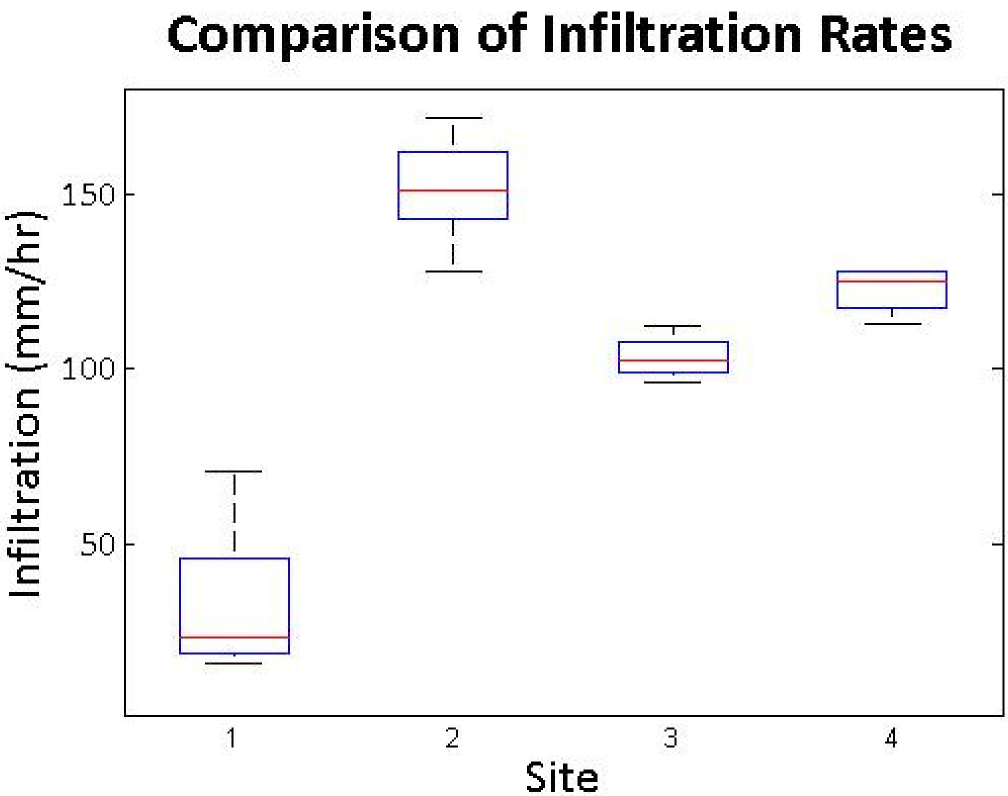

Figure 16. Infiltration rates occurring in similar mesquite rangelands are plotted and compared above. The x-axis represents a specific research site and the y-axis is the infiltration rate in mm/hr. Site 1: Fort Hood: current study site. Site 2: Wood *et al.* 1981 a. & b. Site 3: Brock *et al.* 1982. Site 4: Knight *et al.* 1983

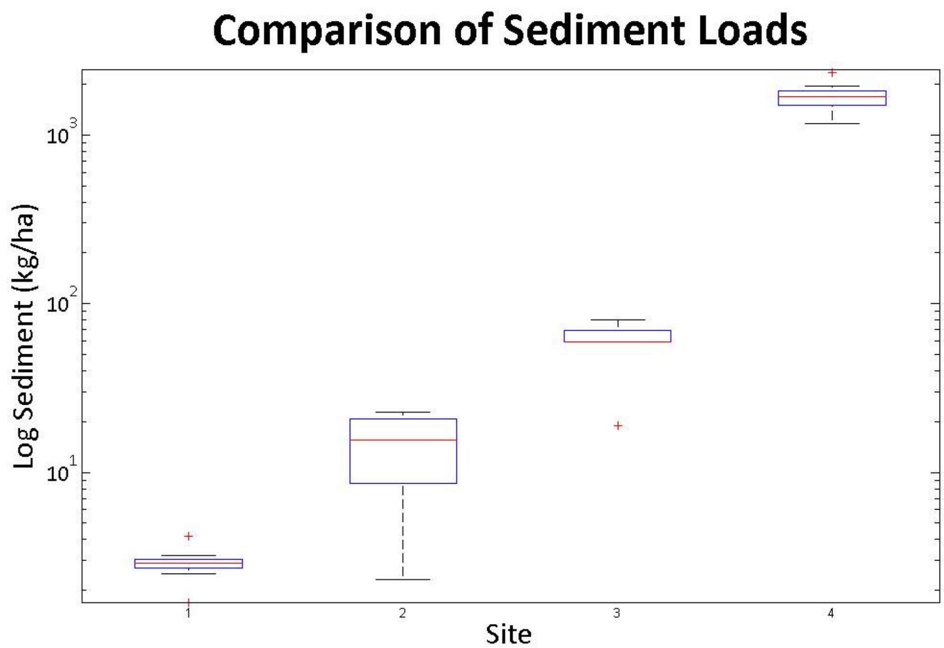

Figure 17. Sediment loads occurring in similar mesquite rangelands are plotted and compared above. The x-axis represents a specific site and the y-axis is the sediment load in kg/ha (log). Site 1: Fort Hood: current study site. Site 2: Wood *et al.* 1981 a. & b. Site 3: Brock *et al.* 1982. Site 4: Knight *et al.* 1983

Based on comparisons to other studies, the research site at Fort Hood could possibly be described as an example of mixed recovery. The infiltration rates observed are comparatively lower than those occurring at other similar research sites. However, the sediment loads are also lower than those occurring at other similar research sites. Upon examination of infiltration rates, it appears that the study site at Fort Hood may have experienced more severe degradation in the past than that occurring on grazed landscapes and naturally occurring shrub landscapes. Heavy military traffic, which is primarily made up of vehicular traffic, in conjunction with continued grazing on the site could explain observations of low infiltration rates and high runoff amounts. The role of past cultivation could also have some influence on the sites hydrologic properties; however, the site has not been cultivated for many years. Sediment load amounts are interesting because they show that the landscape to have recovered considerably well. Sediment loads on the study site are low and far from levels that would be concerning. The thick grass and woody plant cover may explain the low amount of erosion occurring at the site. The small hillslope gradient could also be a contributor to the reasonable amount of erosion observed because it was more difficult to concentrate flow in order to detach and transport particles away from the soil surface.

Challenges and uncertainties

A large-scale rainfall simulation of this magnitude has substantial benefits, but contains issues that must be addressed. Each hydrologic variable had complications that likely altered the data; however, the impact of such occurrences was likely small and does not detract from the overall validity of the experiment.

Precipitation

Precipitation across the plot indicated consistency among each simulated rainfall event. The range of precipitation falling on the plot is represented by 3-D graphics and histograms above. Ideally, rainfall across the plot would be normally distributed on the histograms. As the histograms show, there are some trials where the distribution is better than others.

Another issue that occurred with precipitation measurements was the manner in which the data were collected. Each time research members entered the plot there was likely to be some difficulty reading the rain gauges. During the simulations and readings, some of the rain gauges were knocked over and unable to be read. Fortunately, there was not an instance where more than five rain gauges went unaccounted for. Some outliers also occurred in the rainfall measurements because the rain gauges had exceeded their capacity. At other points, rain gauge measurements were incorrect due to a leak that had developed in one of the hoses. This increased the amount of water received by a rain gauge on the corner of the plot. Some of these outliers were excluded from the rainfall data. In summary, the collection of precipitation across the plot was thorough and is unlikely to contain extensive amounts of error.

Runoff and infiltration

Runoff and infiltration values are wide ranging and indicate the variability between trials. Most of this variation can be explained by the antecedent moisture conditions on the plot. Runoff generation increased and infiltration decreased throughout trials as one would expect. A small part of the variation may have been the result of unwanted ponding on the plot. This occurred because there was a very light gradient on the hillslope and it was difficult to orient the flume so that all measurable runoff was captured. Ideally, ponding would be localized and not be deeper than a natural event not confined by a border. However, this was not the case and ponding did occur at deeper depths than idealized, sometimes in excess of an inch. This may have underestimated runoff and overestimated infiltration.

Another impact worth mentioning was the method used to read rain gauges on the plot. The manual collection of rainfall measurements required multiple entries into the plot. Such activity noticeably degraded vegetation and may have caused some surface soil compaction. This could have had an overall influence on runoff and infiltration measurements. Although its influence is likely small, runoff values would be less than those observed and infiltration values would be greater than those observed in such a scenario.

Bulk density

Data in this experiment support the conclusion that the site has potentially experienced significant compaction as a result of long-term training by heavy armor, grazing, and past cultivation. However, bulk density, a useful indicator of compaction, is not included in this study. Samples are currently being collected and analyzed, but at the time of this writing have not been completed.

Conclusions

This study exemplifies the use of large-scale rainfall simulation as a mechanism to evaluate the hydrology of rangelands. The Fort Hood research site appears to be a degraded site that has undergone a mixed recovery. In this case, a mixed recovery describes the Fort Hood site's long lasting hydrologic alteration contrasted with an apparent recovery away from large amounts of erosion. Such a conclusion may bring into question the ultimate recovery of many landscapes to their past hydrologic regimes. The anthropogenic changes that continue to alter the environment are unlikely to cease and the role of impact assessment will grow larger. The conclusions of this study can be further supported by bulk density measurements and measurements of compaction. These measurements are scheduled to occur in the near future.

An additional use of this study in the future will be its comparison to upcoming large-scale rainfall simulations at Fort Hood. Two more large-scale rainfall simulations are currently scheduled to occur within the next two years. One will assess a highly altered site where tank traffic has recently occurred (less than a year ago) and another will examine the hydrologic effects of restoration by examining a compost application site.

The investigation of (1) the extent of degradation occurring on rangelands (2) the resiliency of a landscape to rebound to a past hydrologic regime is important for hydrologic assessments of rangelands. At the Fort Hood study site, surface runoff values on the site accounted for 28.7% to 64.9% of the total application and infiltration rates ranged from 15.1 mm/hr to 70.1 mm/hr. Sediment loads varied slightly and ranged from 1.7 kg/ha to 4.2 kg/ha. Future questions to be investigated include whether or not this site was unique and if there a long term shift towards permanently altered rangelands. A perplexing issue occurring at the Fort Hood site was the extensive and apparently healthy vegetation cover. This likely explains the low sediment loads observed on the site, but to what extent is the vegetation stressed by poor infiltration rates and high runoff amounts? The initial intent of this experiment to provide a baseline for hydrologic comparison has potentially produced intriguing questions regarding the long-term resilience of disturbed rangelands.

REFERENCES

Asner GP, Archer S, Hughes RF, Ansley RJ, Wessman CA. 2003. Net changes in regional woody vegetation cover and carbon storage in Texas Drylands, 1937-1999. *Global Change Biology* **9**: 316-335.

Blackburn WH, Pierson FB, Hanson CL, Thurow TL, Hanson AL. 1992. The spatial and temporal influence of vegetation on surface soil factors in semiarid rangelands. *Transactions of the ASAE* **35**: 479-486.

Blackburn WH, Pierson FB, Seyfried MS. 1990. Spatial and temporal influence of soil frost on infiltration and erosion of Sagebrush Rangelands. *Water Resources Bulletin* **26**: 991-997.

Brady NC, Weil RR. 2010. *Elements of the Nature and Properties of Soils*. Prentice Hall: Upper Saddle River, New Jersey: 500-507.

Brock JH, Blackburn WH, Haas RH. 1982. Infiltration and sediment production on a deep hardland range site in North Central Texas. *Journal of Range Management* **35**: 195-198.

Dasgupta S, Mohanty BP, Kohne JM. 2006. Impacts of juniper vegetation and karst geology on subsurface flow processes in the Edwards Plateau, Texas. *Vadose Zone Journal* **5**: 1076-1085.

Gregory L, Wilcox BP, Shade B, Munster C, Owens K, Veni G. 2009. Large-scale rainfall simulation over shallow caves on karst shrublands. *Ecohydrology* **2**: 72-80.

Knight RW, Blackburn WH, Scifres CJ. 1983. Infiltration rates and sediment production following herbicide fire brush treatments. *Journal of Range Management* **36**: 154-157.

Li YX, Tullberg JN, Freebairn DM. 2001. Traffic and residue cover effects on infiltration. *Australian Journal of Soil Research* **39**: 239-247.

Moreno-de las Heras M, Nicolau JM, Merino-Martin L, Wilcox BP. 2010. Plot-scale effects on runoff and erosion along a slope degradation gradient. *Water Resources Research* **46**: W04503.DOI: 10.1029/2009WR007875

Munster CL, Taucer PI, Wilcox BP, Porter SC, Richards CE. 2006. An approach for simulating rainfall above the tree canopy at the hillslope scale. *Transactions of the ASABE* **49**: 915-924.

Scanlon BR, Jolly I, Sophocleous M, Zhang L. 2007. Global impacts of conversions from natural to agricultural ecosystems on water resources: Quantity versus quality. *Water Resources Research* **43**: W03437.DOI: 1029/2006WR005486.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://soildatamart.nrcs.usda.gov/Manuscripts/TX099/0/coryell.pdf. Accessed: December 15. 2010.

Taucer PI, Munster CL, Wilcox BP, Owens MK, Mohanty BP. 2008. Large-scale rainfall simulation experiments on Juniper Rangelands. *Transactions of the ASABE* **51**: 1951-1961.

Van Auken OW. 2000. Shrub invasions of North American semiarid grasslands. *Annual Review of Ecology and Systematics* **31**: 197-215.

Wilcox BP. 2002. Shrub control and streamflow on rangelands: A process based viewpoint. *Journal of Range Management* **55**: 318-326.

Wilcox BP. 2010. Transformative ecosystem change and ecohydrology: Ushering in a new era for watershed management. *Ecohydrology* **3**: 126-130.

Wilcox BP, Huang Y, Walker JW. 2008a. Long-term trends in streamflow from semiarid rangelands: Uncovering drivers of change. *Global Change Biology* **14**: 1676-1689.

Wilcox BP, Taucer PI, Munster CL, Owens MK, Mohanty BP, Sorenson JR, Bazan R. 2008b. Subsurface stormflow is important in semiarid karst shrublands. *Geophysical Research Letters* **35**: L10403.DOI: 10.1029/2008GL033696.

Wilcox BP, Wood MK, Tromble JT, Ward TJ. 1986. A hand-portable single nozzle rainfall simulator designed for use on steep slopes. *Journal of Range Management* **39**: 375-377.

Wood MK, Blackburn WH. 1981a. Grazing systems - their influence on infiltration rates in the Rolling Plains of Texas. *Journal of Range Management* **34**: 331-335.

Wood MK, Blackburn WH. 1981b. Sediment production as influenced by livestock grazing in the Texas Rolling Plains. *Journal of Range Management* **34**: 228-231.

CONTACT INFORMATION

Name:	Maxwell Curtis Lukenbach
Professional Address:	c/o Dr. Bradford Wilcox Department Ecosystem Science and Management MS 4227 Texas A&M University College Station, TX 77843
Email Address:	maxluke@gmail.com
Education:	B.S., Environmental Geosciences, TAMU, May 2011 Undergraduate Research Scholar Phi Kappa Phi Phi Beta Kappa