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Geog 575
Final Class Project

John Marshall, GIS Certificate Program
Digital Compilation and Database Design
An Analysis of Plant Moisture Indexes and Potential Dependent Weed Indexes for Wetland Prairie Vegetation at the Muddy Creek Wetland Mitigation Bank

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Enclosed:

1. Term Paper

2. CD:
    a. Term Paper-Final Class Project
    b. Power Point-Final Class Project
    c. Project Proposal-Preliminary Class Project Proposal

cc: JM/Records

Plant Moisture and Weed Indexes as Indicators of Native Wetland Prairie Vegetation Performance at the Muddy Creek Wetland Mitigation Bank

Introduction

Anecdotal observations suggest there may be a negative relationship between dominance by weed species that invade wet prairie mitigation bank restoration sites and dominance of plant species tolerant of seasonally saturated or flooded soil conditions (facultative wetland prairie species). A weed index and a moisture index were calculated for randomly selected plant sample plots collected at the Muddy Creek Wetland Mitigation Bank in Benton County, Oregon (Township 14S, Range 5W, Section 9, Tax Lot 300). The derived indexes are interpolated to generate moisture and weed "surfaces" using ArcInfo spatial analyst tools and analyzed in an Excel spreadsheet scatter plot to help determine if sample plot weed indexes exhibit a dependent relationship with sample plot moisture indexes in the area sampled.

The Muddy Creek Wetland Mitigation Bank was chosen because: 1. it targets historically important wetland prairie recovery objectives, 2.it is obligated to meet moisture index and weed performance standards, 3. the mitigation bank sponsors have done an exceptional job of tracking and recording geographically referenced vegetation response, and 4. the bank sponsors have given permission to use their 2008 monitoring data in this project (Chris Kiilsgaard personal communication).

The Bank site is on a terraced floodplain of Muddy Creek (Figure 1). The local topography can be described as a series of low-profile ridges and level-bottomed swales trending in a SE-NW direction with the lobes of the ridges grading into a largely flat floodplain (Figure 2). Overall, topography for the site is relatively flat with 9 vertical feet of relief between high and low spots on the property. The *Soil Survey Geographic database (SSURGO)* displays the presence of three soil series (Figure 3), Awbrig (Hydric), Waldo (Hydric), and Coberg (Upland). The mitigation bank has targeted goals to achieve establishment of a mosaic of shallow-water palustrine emergent wetland and wetland prairie grassland habitats. About 7-acres will be maintained as riparian forested wetland associated with Muddy Creek (Kiilsgaard and Reams 2007).

Background

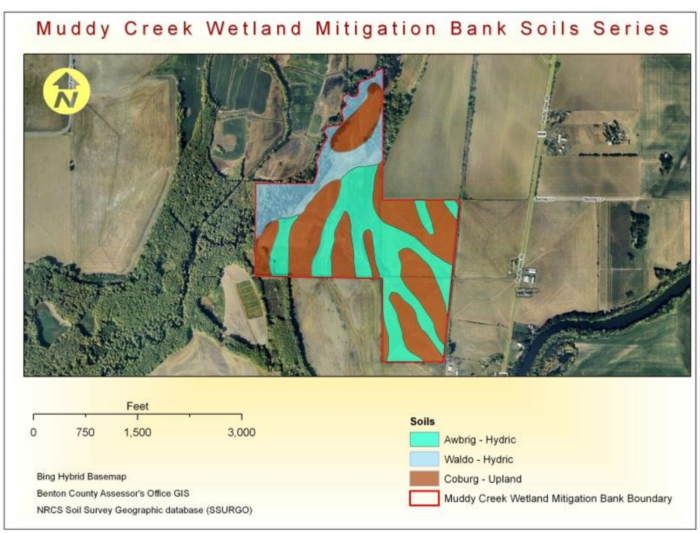
The concept of mitigation to both avoid and off-set losses to sensitive and highly functional aquatic resources has been adopted and utilized by both Federal and State regulatory programs in Oregon for over 25-years (Marshall 1987). Private and public sector developers seeking Federal and State permits for their projects are first required to demonstrate the least environmentally damaging practicable alternatives for completing their development proposals has been selected. Then, if any unavoidable adverse impacts to the regulated waters of the state and/or the United States remain, they are generally required to complete a quid-pro-quo action that replaces the impaired or lost aquatic resources. This is called compensatory mitigation.

Figure 1. Muddy Creek Wetland Mitigation Bank Location

Figure 2. Muddy Creek Wetland Mitigation Bank Elevations

For the majority of the time period in which compensatory mitigation has been applied and enforced both in Oregon and nationally, the compensatory actions were completed after the development related damages had occurred and, if the mitigation actions ever did reach their intended goals, it was often many years after the original aquatic areas had been destroyed (National Research Council 2001). In an effort to help eliminate or reduce the uncertainty of compensatory mitigation success and the time lags between

Figure 3. Muddy Creek Wetland Mitigation Bank Soils.



aquatic losses and aquatic replacements, a concept of mitigation banking was developed and eventually applied through Oregon Revised Statutes (ORS 196.668 – 196.692), Oregon Administrative Rules (OAR-085-0720 – OAR-085-0760), and Federal Regulations (Federal Register / Vol. 73, No. 70 / Thursday, April 10, 2008 / Rules and Regulations).

A mitigation bank is generally a parcel of land established for the sole purpose of restoring, creating, enhancing, and protecting the natural resource values of the area inside the bank boundary. An Interagency Review Team (IRT), largely comprised of representatives of Federal and State resource and regulatory agencies, watches over the establishment and operations of the mitigation banks during their regulatory life span.

There has been a growing emphasis on utilizing mitigation banking to help replace historically important aquatic resources that have been severely reduced in size and fragmented (http://www.dfw.state.or.us/conservationstrategy/) since European settlement. For example, about 77% of the Columbia River Estuary tidal swamps (forested wetlands) have been diked and converted to pasture land and other alternative uses (Thomas, D. 1983) and nearly 99% of the original Willamette Valley wetland prairie and oak savannah has been lost to agricultural conversions and urban development (Johannessen et al 1971, Christy and Alverson 2004). In addition to agricultural conversion and urbanization, post European displacement of aboriginal burning has created an indirect threat to Willamette Valley prairies by allowing increased colonization by woody plants and nonnative invasive forbs and grasses (Pendergrass 1995).

Willamette Valley prairie-oak savannas are important to a number of species, including several threatened and endangered plants and a number of migratory birds (Titus et al 1996). They often absorb floodwater, improve water quality by filtering pollutants and nutrients from runoff, and provide many unique opens space and scenic opportunities to outdoor enthusiasts (Bosse 2008).

One of the duties of the IRT is to help the mitigation bank sponsors develop and operate a credit and debit allocation system sensitive to the quality and quantity of the resources provided and protected at the individual mitigation banks. In order to sell mitigation credits, wetland mitigation banks are required to achieve or exceed measurable performance standards. A number of the performance standards applied are associated with targeted vegetation responses. For example, wetland mitigation bank sponsors are generally required to demonstrate they have established plant communities dominated by plants typically associated with wetlands. Additional vegetation performance standards are applied that require minimum native plant species percent cover thresholds and maximum thresholds on percent cover by non-native invasive plant species. Specialized plant diversity and focal species performance standards are also applied to mitigation banks that propose wet-prairie recovery in one or more of their management units (Marshall 2007).

There are a variety of vegetation management options available to mitigation bank sponsors including but not limited to controlled burning, mowing, herbicides, solorization, and sod removal (Pfeifer-Meister 2008). Ideally, compensatory mitigation site preparation and on-going management methods should be completely beneficial or, at a minimum, entirely benign to the ecosystems in which they are applied. However, any management application that favors habitat conditions for one group of species likely poses disadvantages for others and herbicides in particular can have more direct adverse effects on non-target species (Tarkowski 2004, Water Resources Research Institute 1976, Water Resources Research Institute 1993).

Every site is somewhat unique in terms of opportunities and constraints that would dictate the best prescription for prairie restoration. In most cases no one single technique is employed but a combination of several. However, herbicides are currently one of the primary methods Willamette Valley mitigation bankers choose to help achieve their vegetation performance standards. The reason for this is relatively straightforward. If a bank fails to meet its vegetation performance standards, it may be partially or completely suspended from selling credits by one or more of the IRT regulatory agencies until the performance standards are met. The use of herbicides significantly decreases the banker's risk of having their credits suspended for failure to meet their vegetation performance standards. There are alternatives to using herbicides but few of those options are considered as effective.

There is one tool that is commonly deployed by mitigation bankers but that remains relatively overlooked by researchers, with emphasis on its potential to assist in weed management. A number of Willamette Valley mitigation bankers are currently using shallow sloped berms to keep water on their bank sites longer and more frequently into the growing season. While some may consider this a compromise merger between old school and newer more progressive strategies aimed at ecosystem recovery, there is an ecological foundation for the utilization of water control methods. In addition to fire, periodic flooding was likely one of the disturbance factors that historically helped maintain wet prairies and the historic flood regime of the Willamette River and its tributaries has been significantly altered by upstream water storage dams, diking, ditching, and a variety of other manmade flood control efforts (Pendergrass 1995). So a management strategy that can, even to a limited degree, mimic historic flood frequency and duration intuitively makes sense.

The constructed berms are generally shallow sloped (<7:1) curvilinear earthen features placed at the lower elevations on the bank sites and perpendicular to the gradient of gently sloping (generally < 2:1) valley bottomland. They are usually placed at bank sites with heavy clay soils that are thought to have formerly supported wetland prairie. These berms are left open-ended and are often designed and built more or less in a horseshoe shape. Some are combined with overflow spillways and weirs but most are just earthen berms without the auxiliary structures.

During rainfall and flooding events sheet-flow water backs up behind these berms instead of moving more directly downslope and into nearby adjacent ditches and streams. During late spring to mid-summer, the water usually completely evaporates from the soil surface. During period(s) of inundation, the water is typically deepest behind the berms and becomes progressively shallower upslope. Obligate wetland plants tend to occupy the areas closest to the berms but the higher elevations behind the berm tend to be colonized by facultative wetland species. This also happens to be a moisture regime in which many native Willamette Valley wetland prairie plants are uniquely adapted to survive and flourish in (Schwindt 2006).

So why consider these berms a "compromise" between old-school and new-school ecosystem restoration thinking? The technique of choice for wetland mitigation for the majority of their regulatory history (old-school) has been the establishment of what are now considered to be mismatched hydrogeomorphic features (Gwin et al 1999) on the landscape by 1. digging depressional features to intercept the water table and 2. building enclosed dikes to hold water. Both of these techniques were designed to hold permanent surface water and were primarily targeted towards waterfowl production. When used in combination with strategies to establish plants considered nutritional for waterfowl, they are often coined under the term "moist soil management." Others have used the term "duck doughnuts" as a pejorative adjective. The problem was not so much that this strategy didn't work. In fact, it was and continues to be a very effective means for establishing waterfowl breeding and wintering areas. The problem was, for the most part, it was essentially the only tool in the toolbox that wildlife managers and wetland regulators were willing to employ and that it was focused on habitat for waterfowl to the extent it excluded historically important habitat types and the imperiled species they support.

The emphasis has now shifted toward targeting the recovery of historic ecosystem (Oregon Department of Fish and Wildlife 2006) conditions (new-school) to the degree practicable given the considerable list of present day constraints associated with achieving that objective. For the Willamette Valley that means targeting seasonally flooded wetland and upland fire maintained prairie oak savannahs in a matrix dominated by graminoid/forb mixes interspersed with a mosaic of shallow depressional forb dominated vernal pools, sedge and rush emergent wetlands, oxbow lakes, and meandering sloughs. Sensitive species associated with these habitat type include but are not limited to Bradshaw's lomatium, Willamette daisy, Nelson's checkermallow, western pond turtle, and Oregon chub (Titus et al 1996).

Emphasis has also shifted toward looking for means to restore ecosystems that are relatively self-sustaining and minimizing use of highly engineered solutions. While most natural area managers understand that some level of on-going management will almost always be necessary (Center for Natural Land Management 2004), there are a number of site preparation strategies that can be used to help minimize the frequency and intensity of on-going management practices (Norman 2008).

Historic habitat recovery objectives are embraced and targeted by most of the Willamette Valley mitigation bankers as evidenced in their selected performance standards for wetland prairie condition. The utilization of the curvilinear berm strategy described above is now accepted by many wildlife managers and regulators and is considered by most to be evidence of an "environmentally sensitive" alternative to the heavily engineered water control structures of the past. Moreover, they are considered by many to reflect a management emphasis committed to restoring relatively self-sustaining systems. This is not only environmentally beneficial, it may also prove economically beneficial for bankers by reducing some of the maintenance costs associated with calculating the long-term stewardship endowments they are obligated to pay for.

Problem Statement

There is considerable evidence that a major breakthrough has been made in the wetland mitigation paradigm. Mitigation bank sponsors are moving away from old-school techniques focused on highly engineered permanent water structures exclusively targeted for waterfowl, to successfully implementing the recovery of rare wetland prairie types that are vegetatively indistinguishable, or in better condition, than their unmanaged native prairie counterparts (Schwindt 2006). However, herbicides play a large role in that success story and there is little evidence that researchers are currently investigating the potential non-target species related consequences of their use. Some would argue that if the land were left in agricultural production, the use of herbicides and potentially other pesticides would be even more concentrated. While this is also an area that has not been empirically investigated, even if it is true restoration ecology should be based on a philosophy of "do no harm." If there are less environmentally damaging alternatives to the use of herbicides we should be making every effort to point research toward investigating those alternatives.

Anecdotal observations suggest there may be a negative relationship between dominance by weed species (defined as both nonnative and nonnative invasive) that invade wet prairie restoration sites and dominance of plant species tolerant of seasonally saturated or flooded soil conditions (facultative wetland prairie species). The preponderance of weeds tend to be observed at the two extremes of the Willamette Valley wet-dry moisture range while the intermediate portion of moisture scale generally tend to be relatively less weed encumbered (Schwindt 2006), the most blatant exception being those areas heavily invaded by reed canary grass.

"Environmentally sensitive" water control structures that conform to a hydrogeomorphic (Adamus 2001) character of the landscape may be a viable means to help maintain relatively self-sustaining native wetland prairie plant communities in a manner that significantly reduces our dependence on herbicides. This is not to suggest we should stop looking at other solutions (e.g., controlled burning).

The role hydrology plays in wetland prairie recovery should be investigated more thoroughly. However, surface and groundwater monitoring can be very expensive and time consuming. A surrogate indicator of site water levels such as a plant community moisture index may help expedite such investigations. Moisture indexes have been successfully used to help characterize plant community response to restoration induced changes in hydrologic condition in coastal freshwater tidal marshes (Marshall 1993) and Willamette Valley prairie (Frenkel and Streatfield 1997).

Project Description

The 2008 field data used in this report were collected on a Trimble Geo XT GPS device at the Muddy Creek Wetland Mitigation Bank (Arghangelsky 2009) using 1-square meter field sample frames to evaluate plant species presence and percent cover. Sampling was done through systematic transect and plot sampling from random points as described in Marshall 2007. Data were entered into Vegetation Manager (VEMA Mobile) relational database. Plant community moisture indexes (Marshall 1993, Marshall 2007, Frenkel and Streatfield 1997) for vegetation sample plot data were archived in VEMA tables and reports (VEMA is a customized MicrosoftAccess relational database that can be downloaded from the Northwest Habitat Institute website: http://www.nwhi.org/). The field data were then transferred from the mobile VEMA to a personal computer (PC) version of VEMA using a VEMA mobile desktop management tool in conjunction with Microsoft ActiveSync software.

The bank sponsor provided the bank's VEMA data file for use in conducting this analysis and report. The VEMA data file was received and copied into a desktop computer windows directory and connected to a PC VEMA application using the Linked Table Manager in Data Utilities under Tools. Sample plot weed index and a moisture indexes were calculated from these data. The derived indexes are interpolated to generate moisture and weed "surfaces" using ArcInfo spatial analyst tools and are analyzed in an Excel spreadsheet scatter plot to help determine if sample plot weed indexes exhibit a dependent relationship with sample plot moisture indexes in the area sampled.

Sample Plot Plant Moisture Index

The 1987 Corps of Engineers manual for identification and delineation of wetlands under the jurisdiction of the Clean Water Act (Corps 1987) contains a formula for deriving a "prevalence index" for sample plots collected along a transect traversing a wet-dry moisture gradient. The index is intended to provide a numeric indication when the plant community changes from one dominated by upland species (> 3.0) to one dominated by wetland species (</= 3.0). The point along a transect where the 3.0 threshold is breached is considered a potential wetland boundary if corroborated by soils and hydrology.

Each plant in a sample plot is assigned a numeric wetland indicator status based on the U.S. Fish and Wildlife Service wetland indicator plant species list (Reed 1988):

- Obligate (OBL) = 1.0;
- Facultative-wet (FACW) = 2.0;
- Facultative (FAC) = 3.0; and
- Facultative upland (FACU) = 4.0).

These numbers are used as weighting factors of the percent cover of each respective species observed in a sample plot. Two columns, one containing the percent cover for each species sampled and one column containing the weighted percent cover for each species sampled, are totaled separately. Then the sum of the weighted column is divided by the sum of the unweighted column to derive a prevalence index for the sample plot.

Table 1 Prevalence Index Calculator.

Species	Indicator Status	**Cover Class**		**Weighted Cover Class**	
ALGE	1	63		63	
CAUN	1.5	3		4.5	
DECE	2	15		30	
HOBR	1.5	3		4.5	
JUTE	1.5	15		22.5	
RONU	2	15		30	
		0		0	
MEPU	1	15		15	
ELPA	1	63		63	
		0		0	
		0		0	
		0		0	
BAREG	1.2109	4		4.8438	Prevalence Index
		196		237.34	**1.211**
		192		232.5	**1.211**

Moisture indexes use the same arithmetic used in deriving a prevalence index. But, instead of being used to distinguish a <u>point</u> along a transect line for the purpose of a boundary distinction, they are used to inform an interpolation of a “moisture surface” for the <u>area</u> of terrain in which the vegetation samples are collected. They can be considered rough surrogates for the hydrologic regime for the area in which they are interpolated.

The weed index used for this report also uses the same arithmetic as the prevalence index. But instead of using plant moisture tolerance as the percent cover weighting factor, a scale of “weediness” was derived and used:

Native species = 1.0;
Nonnative species = 3.0; and
Nonnative Invasive = 5.0.

Both the sample plot moisture indexes and the weed indexes for the Muddy Creek Wetland Mitigation Bank were calculated using a semi-automated calculator in the Vegetation Manager (VEMA) relational database used to collect and report the original data.

Data Management and Processing

Moisture indexes were already calculated by VEMA reports. VEMA was used to generate weed indexes by entering the weed scale values describe above into the form dialogue box normally reserved for the species wetland indicator status. A semi-automated calculate moisture index function in the VEMA application file was then used to calculate weed indexes for each sample plot in the database. Once the indexes were calculated they were entered by hand onto a paper form in association with the management units and sample ID numbers indicating the locations where they were collected on the ground. The data form was placed in a file folder and stored for future data entry.

The VEMA sample table containing the sample plot geographic coordinates was added to an ArcMap project. The add xy coordinates option under File menu on the ArcMap toolbar was used to create a sample table event. Latitude was assigned to the y coordinate and Longitude to the x coordinate. A geographic projection of WGS 1984 was assigned to the sample events added. The sample event was then exported to a shape file and added to the ArcMap project.

The attribute table was opened for the newly created sample shapefile and the Add Field option was used to add two new “float” fields, one for moisture index (MIndex) and one for weed index (WIndex). Then ArcMap and the VEMA Site Layout form were opened in split screen on the computer and the scratch paper form containing the derived moisture indexes and weed indexes was placed next to the computer monitor. The moisture and weed indexes were manually added in an ArcMap edit session to each record in the sample shapefile attribute table, while making sure the sample numbers and the latitude and longitude coordinates in the VEMA sample plot properties dialogue boxes matched those in the shapefile attribute table record where moisture and weed index data were being entered. Once data entry was completed, all edits were saved and the ArcMap editing session was stopped.

The next step was to begin compilation of the remaining GIS layers considered necessary to complete the analysis for this project (see Table 2). Several data sources were used:

- Property boundary;
- Soil units;
- Sample grid; and
- 2-foot interval elevation contours.

Geodatabase Development. Data layers that were downloaded from websites or e-mail directories were all placed in a file folder in windows explorer. A number of the layers required selecting and exporting specific components relevant to this project to shapefiles and/or creating layers from tables. This was accomplished in ArcMap. Once all the data were placed in a common file folder in project suitable formats, ArcCatalog was used to create a new personal geodatabase. A new feature dataset was then created to contain each of the feature classes acquired. The feature dataset was assigned a NAD 1983 UTM

Table 2. Geodatabase Design and Data Organization.						
ID	**Data_Layer**	**Spatial_Type**	**Feature_Class**	**ArcInfo_Type**	**Feature_Dataset**	**Geodatabase**
1	Property	Area	Property Boundary	Polygon Feature Class	Project	Weed/Moisture Index Relationship
2	Soils	Area	Soil Series	Polygon Feature Class	Project	Weed/Moisture Index Relationship
3	Vegetation Mindex	Point	Sample Plot Moisture Indexes	Point Feature Class	Project	Weed/Moisture Index Relationship
4	Vegetation Windex	Point	Sample Plot Weed Indexes	Point Feature Class	Project	Weed/Moisture Index Relationship
5	Vegetation Mclass	Area	Moisture Classes	Raster	Project	Weed/Moisture Index Relationship
6	Vegetation Wclass	Area	Weed Classes	Raster	Project	Weed/Moisture Index Relationship
7	Topography	Line	Elevation Contours	Polyline Feature Class	Project	Weed/Moisture Index Relationship

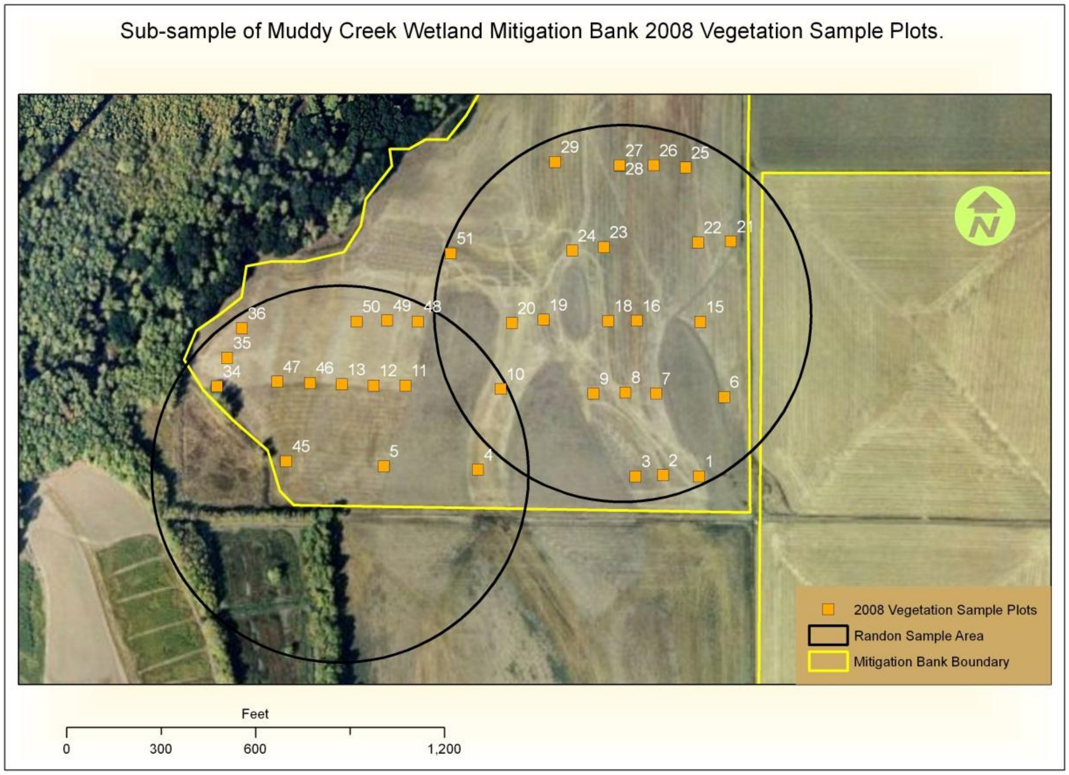
Zone 10N projected coordinate system. The import multiple feature class function was used to import each of the created and acquired data layers into the feature dataset.

Domains, coded and range values, subtypes, and relationship classes were not used in this project. Data organization was primarily done at the feature dataset level in the geodatabase (Kang-tsung Chang 2010). Symbology and classification was assigned by feature class and raster dataset. There were some minor attribute table schema modifications during the creation of the sample grid feature class. Due to time constraints, no metadata was created for this project. A cursory attempt was made to create a topology and associated rules for the different layers. However, difficulties encountered with validation and editing combined with a decision that topology rules were not crucial to the analysis resulted in a decision to delete the topology from the geodatabase and to work without it. Rasters and vector data created during geoprocessing and data analysis were sent to the geodatabase. All figures and maps developed in the data analysis are included in this report.

Analysis Methods and Results

The 2008 sample plot data included a fringe habitat type (forested wetland) that was not a primary area of interest for this project. In ArcMap, Hawth's Tools were used to select three random points inside the mitigation bank boundary. Then a buffer tool in ArcToolbox was used to create a shapefile comprised of circle polygons centered around each of the randomly selected points. A radius of 600-feet was used to maximize the inclusion of the sample plots in the open herbaceous areas but exclude the sample plots in the forested area. One of the three circles created only captured one sample plot so it was deleted. The remaining two circles represent the focal area for the data analysis (Figure 4.).

Figure 4. Muddy Creek Wetland Mitigation Bank 2008 Vegetation Sample Plots Used in this Analysis.

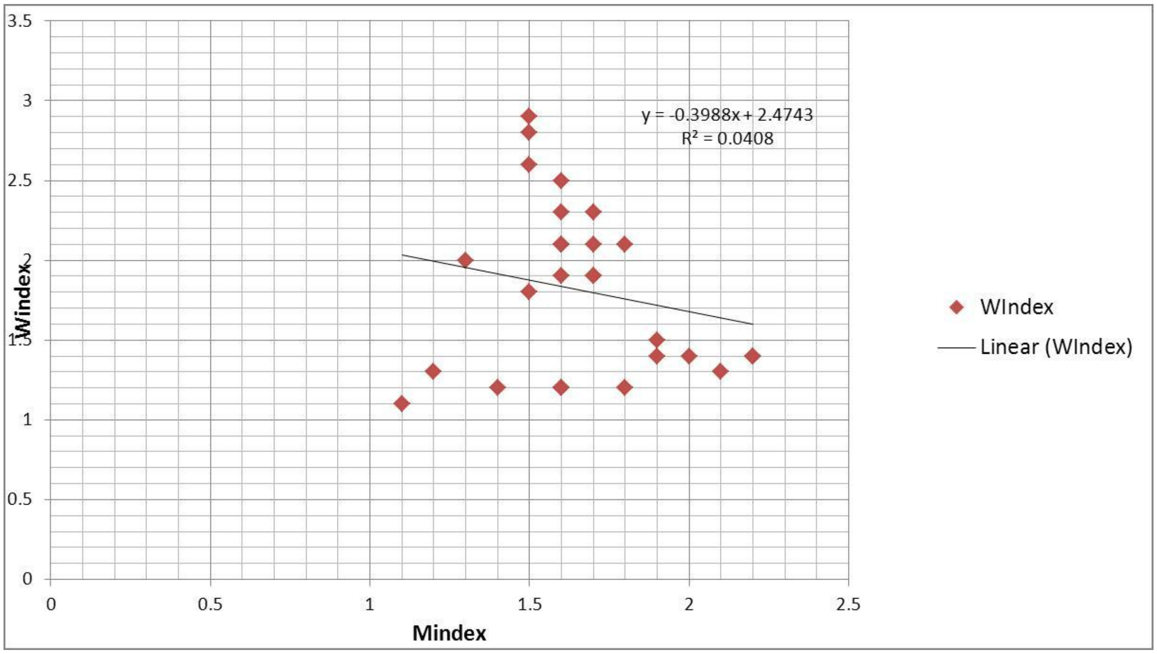


In ArcMap, the clipped VEMA 2008 sample plot attribute table was exported as a text delimited file and then imported into a blank MicrosoftAccess database. The database table was then opened in Microsoft Access and the moisture index and weed index attribute columns were selected, copied from MicrosoftAccess, and pasted onto a MicrosoftExcel spreadsheet. The two columns were selected again in MicrosoftExcel and converted to a scatter plot diagram (see Figure 5). Two of the weed indexes were filtered because VEMA assigned them a zero value. The VEMA sample plot data revealed that these were bare ground plots with no plants in them. VEMA allows users to assign bare ground a moisture index based on associated nearby plants or long-term evidence of the hydrologic regime. Several other sample plot outliers were also filtered out of the data set. They were all in the extreme wet end of the moisture index spectrum (1.0) and were therefore considered to be more representative of an emergent wetland than the drier wetland prairie type on which this analysis is focused.

The scatter plot derived r^2 factor of 0.04 for the remaining (unfiltered) sample plots indicates there is no statistically verifiable evidence the plant community at the Muddy

Creek Wetland Mitigation Bank has a weed index with a dependent relationship with the plant community's moisture index.

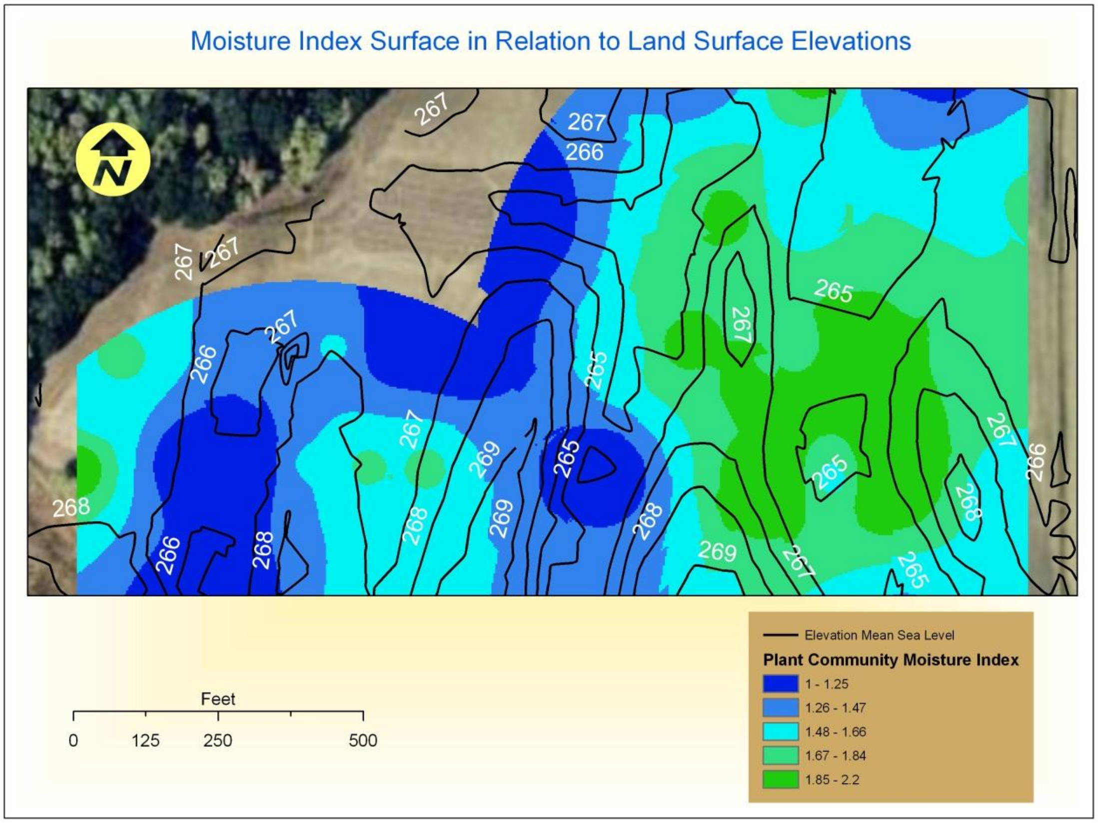
Figure 5. Relationship between moisture indexes and weed indexes at the Muddy Creek Wetland Mitigation Bank.



However, the scatter plot also reveals that most of the 2008 sample plots registered under 2.0 on the moisture index scale. The focal interest in this study is a wetland prairie with a moisture index range generally between 2.0 and 3.0. Only three sample plots at the Muddy Creek Wetland Mitigation Bank fall inside that range. Therefore, the data collected at Muddy Creek Wetland Mitigation Bank neither corroborate or refute the initial hypothesis. They are merely an indication that the Muddy Creek Mitigation Bank is likely wetter than the moisture index regime target for this analysis and is therefore an inappropriate area to test whether a moisture index/weed index relationship exists. The initial question remains open until further investigation can be done at mitigation sites with substantial cover by plant communities in the targeted moisture regime.

Wetland plant communities are generally very sensitive to subtle changes is soil surface and shallow groundwater moisture regimes. A spatial analyst Indirect Weighting (IDW) tool was used to interpolate a moisture index raster surface for use as a base layer and comparison with a 1-foot contour surface elevation overlay layer. One might expect to find a wetter plant moisture index surface at lower elevations and a drier plant moisture index surface at higher elevations. But an ocular view of the plant moisture index surface and the surface elevation contours at the Muddy Creek Wetland Mitigation Bank reveals no discernable consistent pattern of lower moisture indexes at lower elevations and higher moisture indexes at higher elevations (Figure 6).

Figure 6. Plant Moisture Index Surface in Relation to Land Surface Elevations.



Conclusions

An Excel spreadsheet scatter plot calculates an r^2 value of 0.04 for the sampled data, indicating there is no statistically verifiable evidence of a dependent relationship between plant weed indexes and the plant moisture indexes associated with the 2008 sample plots collected at the Muddy Creek Wetland Mitigation Bank. However, the scatter plot also clearly shows the majority of the 2008 sample plots exhibit moisture indexes lower than 2.0, indicating the area represented is trending toward a Palustrine Emergent wetland (Cowardin et al 1979). The moisture index surface interpolated for the area sampled appears to be relatively insensitive to elevation changes across the site. This could be a function of different hydrologic inputs supplementing direct precipitation (e.g., overland sheet flow) and/or be partially or even completely a reflection of the coarseness of the moisture index metric.

No conclusions can be drawn from these data regarding whether there is a dependent relationship between a weed index and an intermediate moisture index surface generally between 2.0 and 3.0. Wet prairie sites with better representation of that moisture index range should be examined.

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Appendix 1. Example of Potential GIS Based Credit Release Schedule for Wetland Mitigation Banks Derived from Interpolated Weed Index Raster Surfaces