Mapping Wetland Features from IFSAR in the Prairie Pothole Region

Janet Gritzner and Bruce Millett, Department of Geography, South Dakota State University, Brookings, SD 57006

bruce.millett@sdstate.edu; janet.gritzner@sdstate.edu

Abstract

The Prairie Pothole Region (PPR) of the US and Canada is ranked number 1 on the list of threatened waterfowl habitats on the continent. Detailed wetland mapping and characterization is prerequisite for wetland protection, management, and restoration. Mapping of the PPR wetlands in the NWI was completed by late 1980s and converted into digital datasets by early 1990s. Wetland features in the PPR have changed considerably in size, shape, water regime, and vegetative stage since the 1980s.

This research looks at rule-based, GIS and remote sensing methodologies for producing detailed map datasets intended to update and enhance the NWI. This work uses airborne Interfermetric Synthetic Aperture Radar (IFSAR) 2005 data products as core datasets: (5-meter Digital Terrain Models (DTMs) and 1.25 meter Orthorectified Radar Imagery (ORI)) to extract and characterize wetland features. Major processing steps entail identifying wetland depressions, extracting vegetation signatures, cleaning up of the data, and merging results.

Introduction

The Prairie Pothole Region (PPR) of the US and Canada is characterized by thousands of shallow water-filled depressions with sizes ranging from a fraction of a hectare to several square kilometers. Described as being one of the most important wetland regions in the world, the area is home to more than 50 percent of North American migratory waterfowl; many of which depend on the prairie wetlands for breeding and feeding. The PPR is ranked number one on the list of threatened waterfowl habitats on the continent.

In addition to its role for waterfowl, pothole wetlands provide valuable ecosystems services. They recharge groundwater systems, hold excess runoff from spring storms and snowmelt which in turn reduce the severity and risk of downstream flooding, and provide water and forage for livestock.

Wetland mapping is prerequisite for wetland development, planning, management, and restoration. While a number Federal agencies map wetlands in support of their Congressional mandate, the U.S. Fish and Wildlife Service (FWS) has the primary of mapping and inventory of all the wetlands of the United States. Largely in response to the passage of the Emergency Wetlands Resources Act in 1986 and its amendments (in 1988, and 1992), the FWS established the National Wetlands Inventory (NWI). This program is primarily designed to produce and distribute detailed maps on the characteristics and extent of Nations' wetlands, construct a wetland's data base, and report to Congress every ten years on the status and trends of the Nation's wetlands.

From the beginning of the program high priorities were set on mapping the coastal zone including the Great Lakes, prairie wetlands, playa lakes, and flood plains of major rivers. Most of the mapping of PPR water resources in the NWI was completed by late 1980s and converted into digital datasets by the early 1990s. A regional survey at this detail and scale is not likely to be replicated in the near future. Pothole wetlands in PPR have changed a great deal since 1980s. Natural fluxes in rainfall, climate change, and agricultural modifications has affected water flow to this dynamic system and is reflected in changes of size, shape, water regime, and vegetated stages of prairie wetlands. Hundreds of wetlands have disappeared from the landscape since the 1980s.

Alternative means of providing detailed maps of wetland resources in the PPR are required to support water resource management, climate change studies, and assessments of wetland modification (i.e., draining and tiling).

This paper reports on research into geospatial methodologies for producing detailed map datasets of water resources in the PPR. Traditional steps for producing the NWI datasets has included: determining project area, acquiring, preparing and reviewing source materials (originally 1:58000 and 1:60000 scale color-infrared photography for northern Great Plains mapping), planning and conducting field reconnaissance of project area, making a photointerpretation imagery, checking the result, transferring data to base maps, checking and reviewing of draft maps, producing final maps for distribution, and digitizing final maps.

Methodological Approach

The methodologies employed in this work use geospatial techniques and multiple datasets to extract wetland features with equivalent mapping detail to NWI. This approach avoids the necessity of extensive manual photo-interpretation, transferring of data to and from different media, and digitizing resulting map products. Datasets required in the research included a variety of remotely sensed data, derivative products, and existing digital wetland datasets (i.e., National Wetland Inventory (NWI). Proof of concept tests were conducted in five contiguous counties in eastern South Dakota: Clark, Hamlin, Deuel, Grant and Codington County.

This application primarily uses airborne Interferometric Synthetic Aperture Radar (IFSAR) 2005 data products as core datasets: 5-meter Digital Terrain Models (DTMs) and 1.25 meter Orthorectified Radar Image (ORI) to resolve water and wetlands at a detailed scale.

Airborne IFSAR Products

IFSAR is an active imaging technique that has been developed for capturing digital elevation data. Relatively high resolution and low cost, X-band IFSAR competes well with LIDAR in low relief, rural and non-forested landscapes. Sample spacing is 2.5 – 10 m; vertical accuracies are 30cm – 3 m RMSE with wide area acquisition capability. Gritzner and Millett (2010) demonstrated the utility of IFSAR DTMs in resolving subtle landscape depressional features in the low lying terrain of the PPR. ORI are high resolution radar images, which can be manipulated by density-slicing routines, but are only useful in combination with other datasets. IFSAR data for 2005 used in the work were provided by Natural Resources Conservation Service (NRCS), United States Department of Agriculture (USDA) for five counties in eastern South Dakota.

Feature Extraction in ArcGIS

Using a 5-m IFSAR DTM as input, ArcGIS ArcHydro Beta Tools are utilized in terrain preprocessing. The first phase of the work is to prescreen sinks and evaluate depressions. All sinks less that 40 x 25 sq m cells (1000 sq m) are eliminated. The depression evaluation tool in ArcHydro Beta generates fully attributed polygon feature classes for depressions and depression areas with data for fill depth, fill area, fill volume, bottom elevation, fill elevation, and drainage area. In this works, sinks or depressions represent wetland features. Problematic is the tendency of the depression evaluation, a fill process in hydrologic modeling, to overestimate the number and size of depressional features; many but not all are actual wetlands. Large semi-permanent wetlands were most easily and accurately resolved, though the depressional features derived from the IFSAR DTM were normally greater in size than the wetlands depicted on National Agricultural Imagery Program (NAIP) imagery (Figure 1). ORI images were used to validate and further characterize wetland features (Figure 2). With a purple to green ramp, lowest values in ORI image are depicted in dark purple and highest values in dark green.

A set of rules were established to guide the remainder of the processing. Depressions used in the application are those that intersect NWI basins. ORI pixel values from 1-20 were extracted to represent water. ORI pixel values 194-254 were extracted to represent vegetation. Only pixels with selected values falling within a depression that intersected an NWI feature were included in the final integrated raster product.

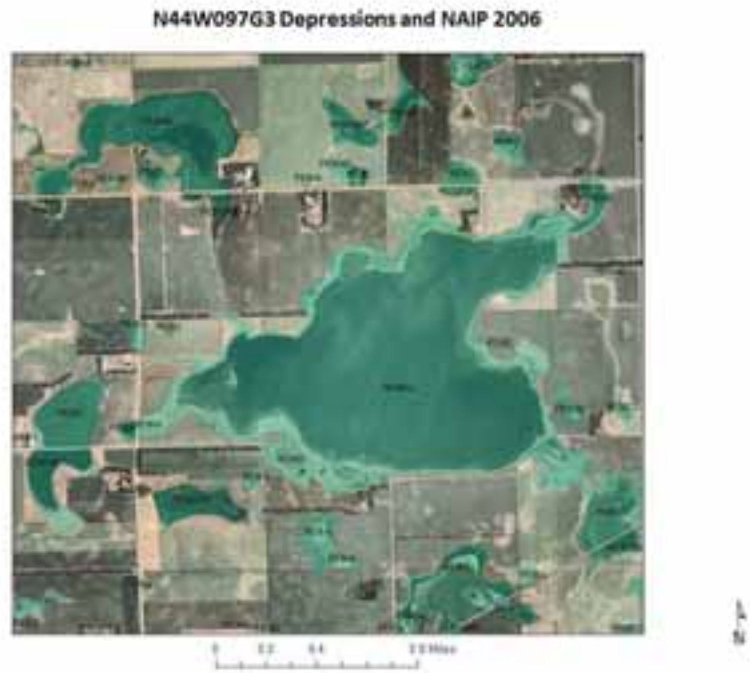

Figure 1

Grover Quadrangle, Codington County, SD depressional features and NAIP image

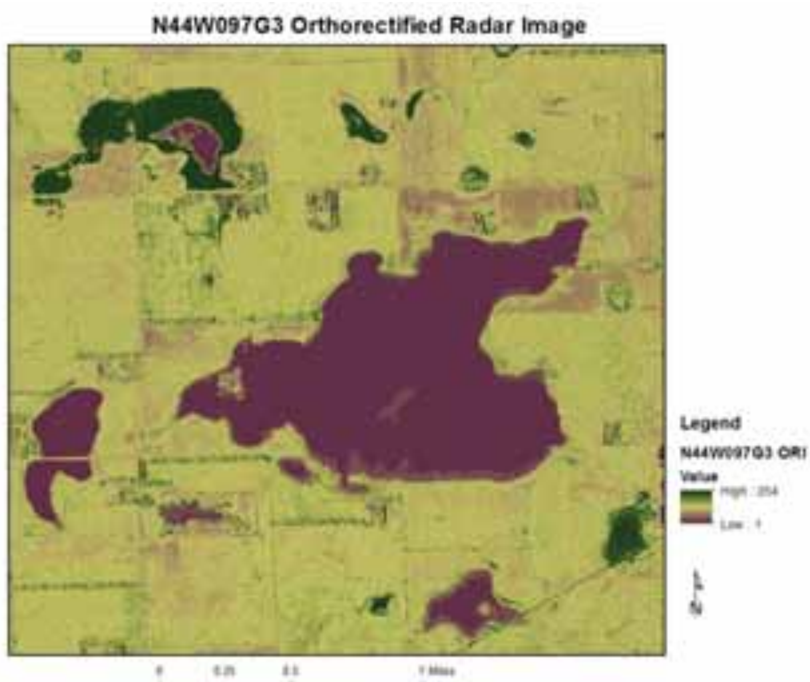

Figure 2

Grover Quadrangle, Codington County, SD ORI image

The results were visually compared to NWI and 2006 National Agricultural Imagery Program (NAIP) digital aerial photography and given the coding of yes, no, or possible wetland feature. Various filtering routines were used to further clean up the data. . Isolated cells were removed from the raster. Boundary clean and majority filter were used to smooth edges of features and fill in missing cells. The integrated raster that included extracted water and vegetation pixels was converted to vector and combined with the depression vector layer (Figure 3).

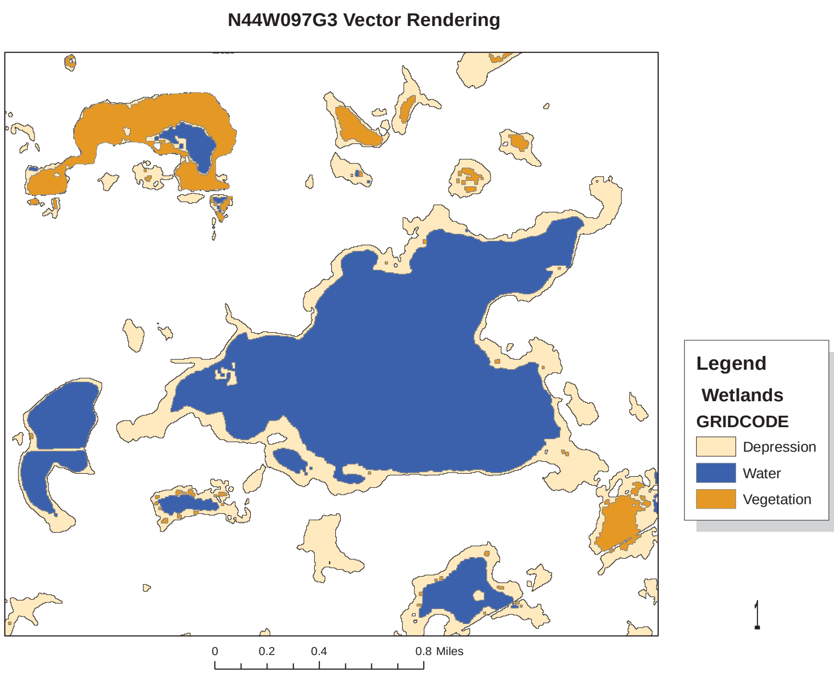

Figure 3

Vector rending of extracted features in Grover Quadrangle, Codington County, SD

Characterizing Wetland Stages

ORI data processing provides an interesting and new map product. Mapping the water and vegetation in combination characterizes the wetland by phases. Wetlands typically move from dry marsh, a completely closed or choked phase <= 25 percent open water with normal rainfall to a regenerating marsh, a hemi-marsh phase 26 to 74 percent open water. Degenerating marsh, also a hemi-marsh phase likely follows due to a variety of conditions that include senescence, insects, disease, and in PPR high water. Sustained high water and/ or muskrat damage results in lake marsh or open water phase with <= 75 percent open water. Draught and draw down can convert open water to dry marsh and so the cycle continues. Stage information: closed, open water, and hemi marsh is added as attributes to vector dataset (Figure 4)

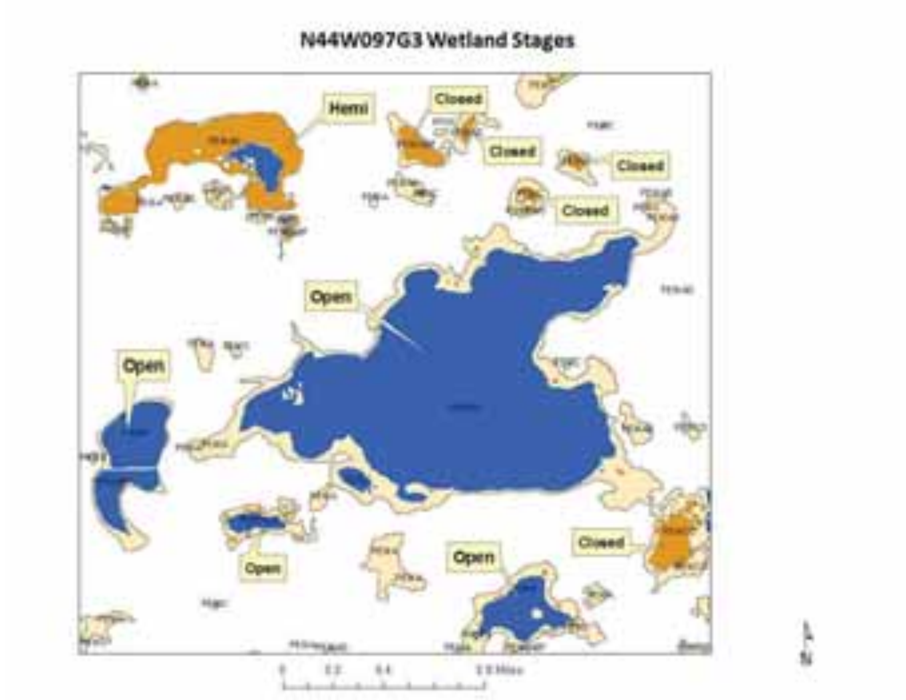

Figure 4

Wetland Stages in Grover Quadrangle, Codington County, SD

Useful IFSAR Products

In this preliminary effort, several useful IFSAR products were identified. Depression evaluation provides a vector rendering of depressional features as well as attribute information on fill area, fill depth, fill volume, fill bottom elevation, fill top elevation, and depression area. Combination of IFSAR DTM and ORI processing reveals intriguing water, vegetation, and depression landscape patterns. Wetland stages may be identified by juxtaposition of water and vegetation in the extracted ORI features.

Conclusions

Mapping wetlands pose considerable challenges and rewards. PPR Wetlands have changed considerably since the NWI was first initiated (Figure 5). IFSAR extracted features compare favorably with NWI and 2006 NAIP imagery and can be used to update NWI especially for larger wetland features. While much of the processing appears straight forward, the real art and science of the project is the interpretation of the radar imagery to develop a pattern recognition strategy. Water in the imagery is relatively easy to detect, but as shown pothole wetlands go through cyclic stages from

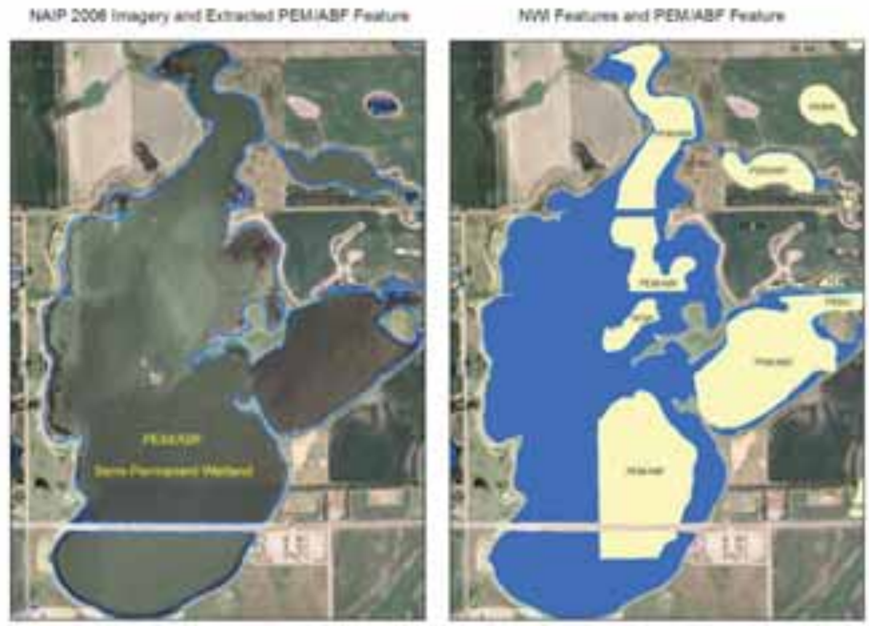

Figure 5

NWI overlaying PPR wetland feature on 2006 NAIP image

being all open water (open stage), to being part water and part vegetation (hemi-stage), to being fully vegetated (closed stage). Pixel values for wetland vegetation vary considerably; only the very highest values were used in this initial test of concept. Depression evaluation yields information on sinks in the data. Not all depressions (sinks) are wetlands and IFSAR does not necessarily pick up every wetland feature. A possible strategy might be to combine high resolution LIDAR as it becomes more available and IFSAR ORI data.

Cited References

Gritzner, J and B. Millett. 2010. Modeling Regional Surface-flow in Glaciated Landscapes. *Proceedings of the ESRI International Users Conference,* San Diego, CA.