Multi-temporal land cover analysis of the south-central Anatolian landscape: Remote sensing as a support tool for studying carbon, water, biogeochemical cycling and landscape changes

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Project Overview and Goals

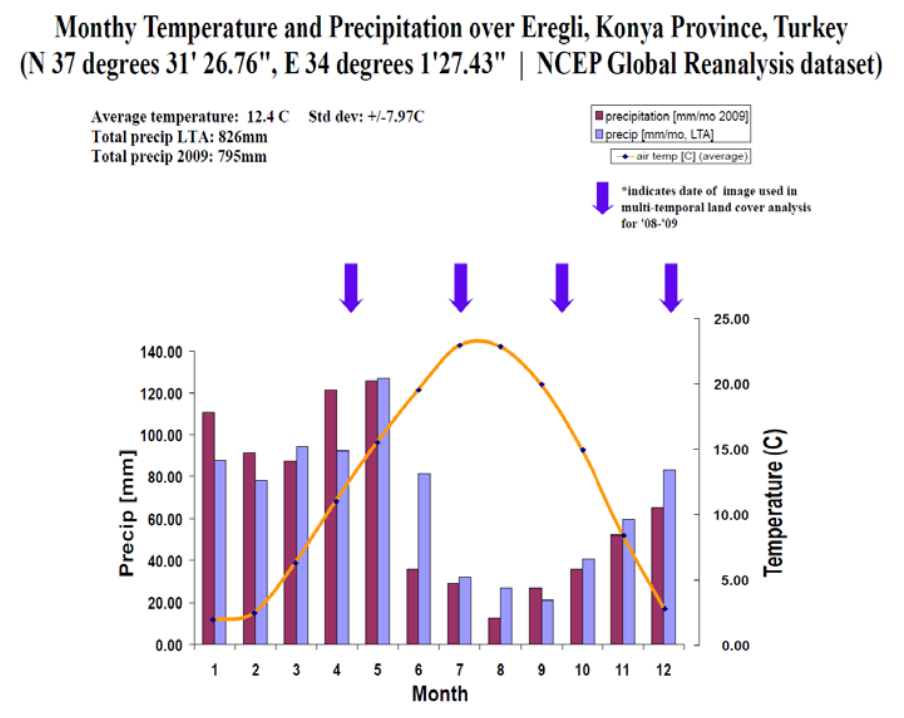
- **Study the impacts of recent agricultural intensification in southern Turkey on soil organic carbon (SOC), nitrogen(N), hydrology at the landscape scale**
- **Characterize landscape as a combination of human land management—physical environmental condition (HLMPC) “sets”**
- **Link regional-scale, remote sensing- based analysis of agricultural and steppe regions with field-scale data on soil organic carbon, irrigation, drainage structures**
- **Share insights on relationships between biogeochemistry, hydrology and land use with farmers, land managers, regional and global biogeochemical and hydrological modelers**

Research questions

- **How do SOC and nitrogen vary across agricultural and steppe landscapes and soil types in south-central Anatolia?**
- **Is SOC and N significantly different between agricultural (irrigated, non-irrigated) and steppe lands?**
- **Is soil type or land use more strongly associated with observed SOC and N?**
- **Variability of SOC, N among HPLMC sets: from a biogeochemical standpoint, what places/practices are best suited for sustainable agricultural intensification?**

Agricultural intensification in Turkey 1970-present

*Approximate location of study area around Eregli, Konya Province



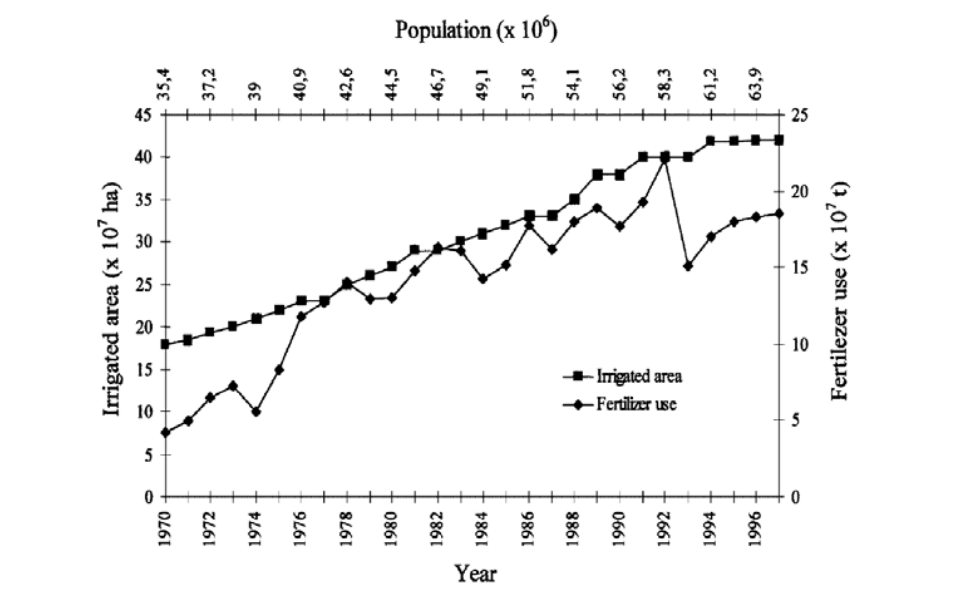


Figure 2. Temporal changes in fertilizer use, irrigated area and population size between 1970 and 1997 in Turkey (Anonymous, 1998; FAO, 2001).

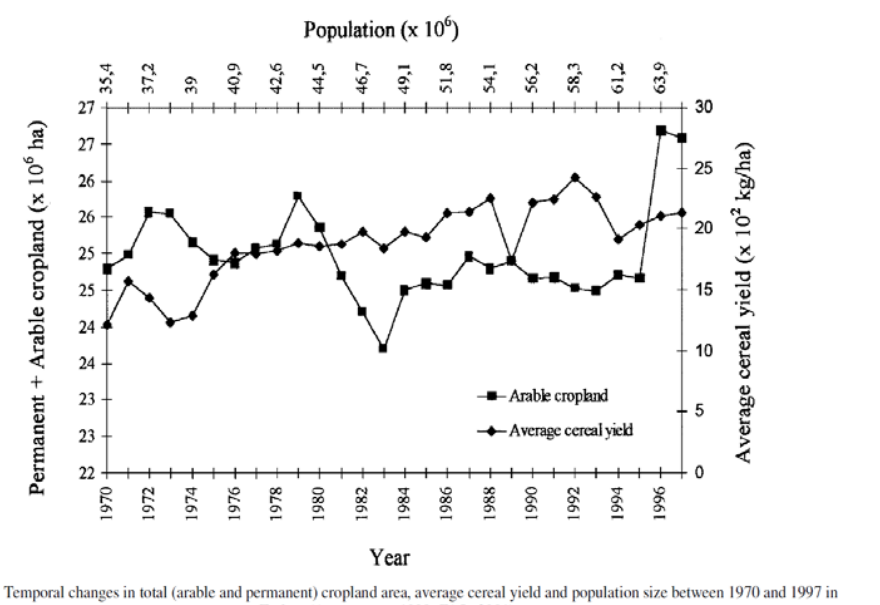


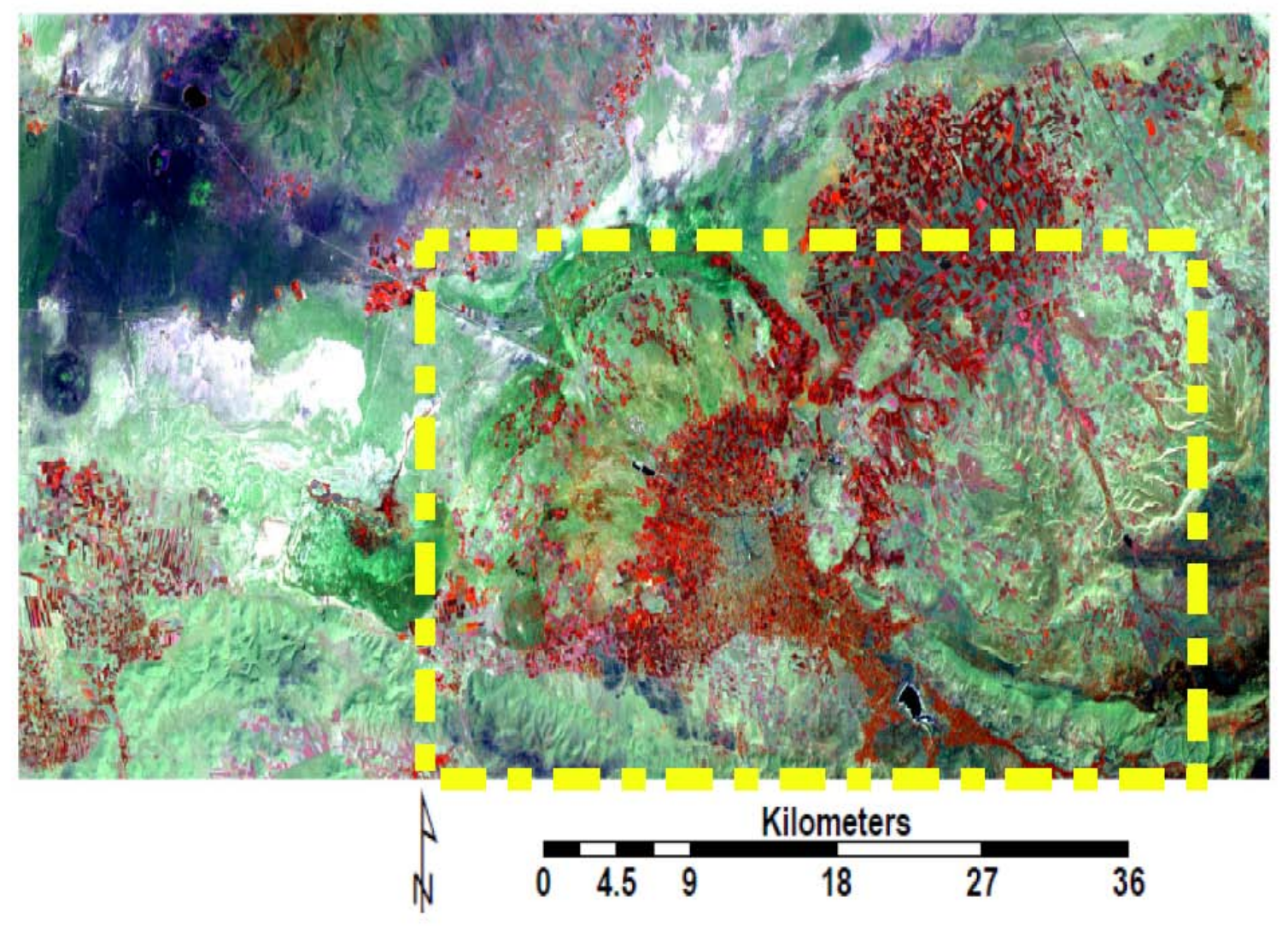
Figure 1. Temporal changes in total (arable and permanent) cropland area, average cereal yield and population size between 1970 and 1997 in Turkey (Anonymous, 1998; FAO, 2001).

Lower figures from Evrendilek and Ertekin (2002), Land Degrad. Develop. 13: 61-67.

- **Irrigated farmland, fertilizer use and population have more than doubled over the last 40 years while the overall area of arable land has increased only 11% (Evrendilek and Ertekin 2002)**
- **Land degradation due to soil erosion, salinity and mismanagement affects over 50% of the country’s farmland every year (Cangir et al. 2000)**
- **Managing agricultural lands for SOC, N conservation may reduce fertilizer costs for farmers, maintain aggregate stability and infiltrability in soils (Brady 2002)**
- **Possible benefits for carbon sequestration—though this is debated in the literature (e.g. Lal 2002, Post and Kwon 2000).**

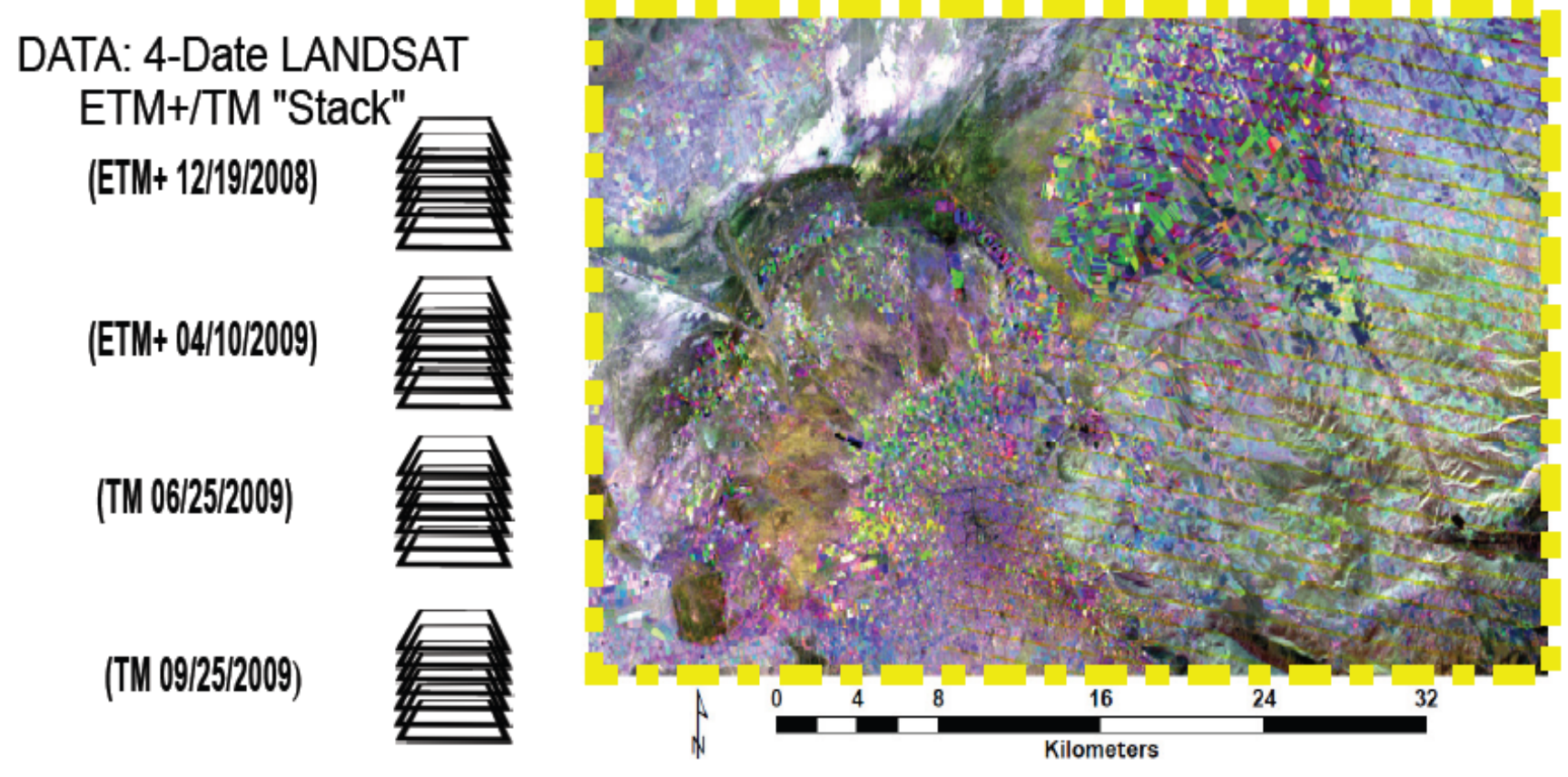
Framework for a multi-temporal land cover analysis

1. Collect LANDSAT TM, ETM+ imagery

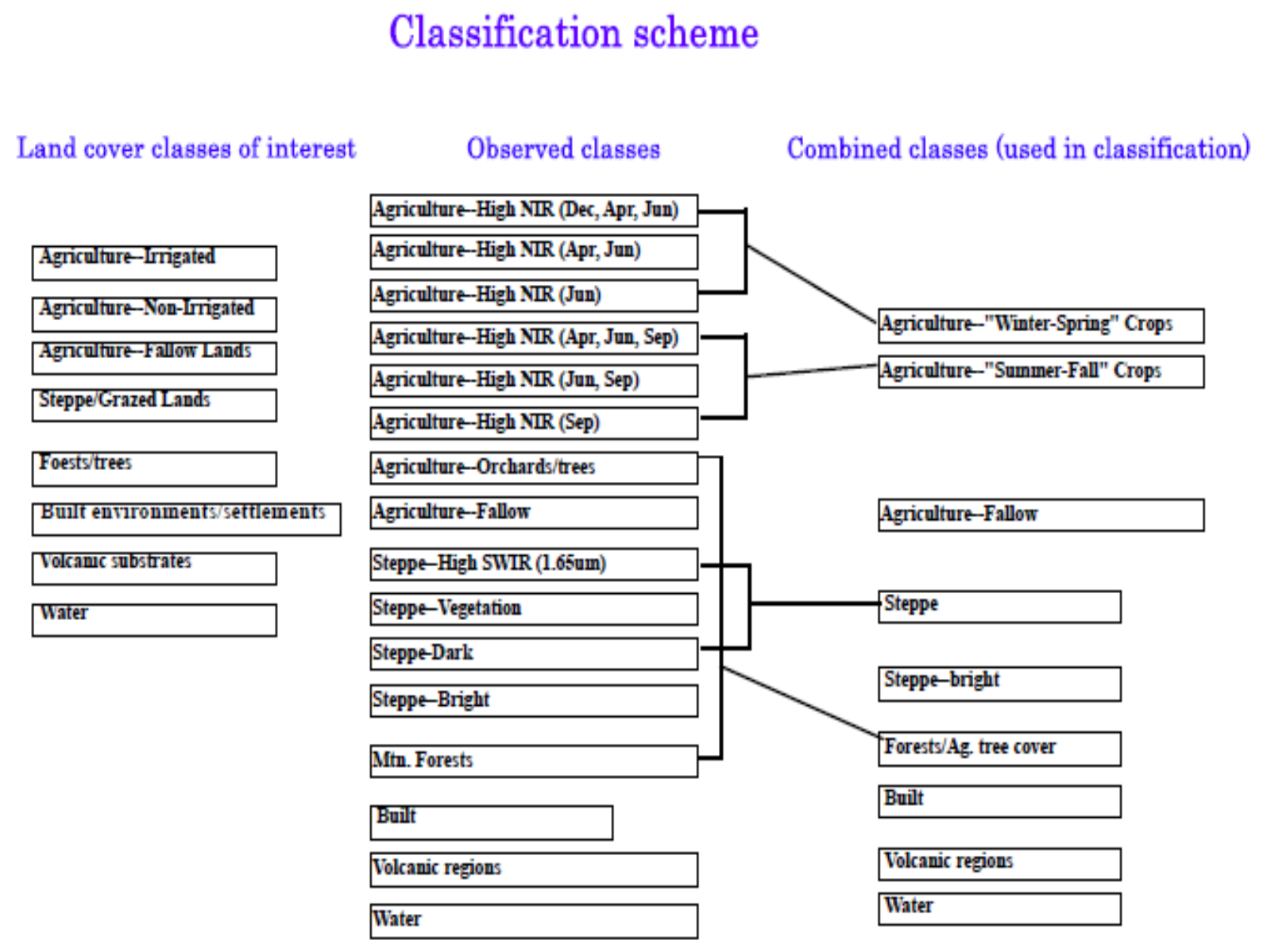


Above: False color Landsat TM image (p.176r034, 06/21/09) over Eregli, RGB: Landsat bands 4,5,3. The landscape is dominatntly semi-arid steppe, but also features forests at higher elevations and the Karapinar volcano field to the Northwest. Agriculture is a clear and pervasive human modification of the landscape. Fields are distributed around towns and on hillsides, at times clearly coinciding with irrigation infrastructure, and have diverse phenological signals. Less clear in LANDSAT-resolution imagery is prevalent use of open steppe lands for grazing.

2. Training site selection from multi-date image stacks



Below: Subset of the Eregli region above in a false-color image of the NIR band, across three dates: June 2009 (RED), September 2009 (GREEN) and April 2009 (BLUE). Here, we study 6-band LANDSAT ETM+ and TM imagery over four dates (December 2008, April 2009, June 2009 and September 2009), using temporal variation in spectral signals to differentiate confusing land cover types, such as steppe and fallow agricultural plots. In continuing work, we will experiment with using vegetation indices (VIs) and other data transform methods to improve characterization of phenological signals.



Classification scheme

Land cover classes of interest

- Agriculture--Irrigated
- Agriculture--Non-Irrigated
- Agriculture--Fallow Lands
- Steppe/Grazed Lands
- Foests/trees
- Built environments/settlements
- Volcanic substrates
- Water

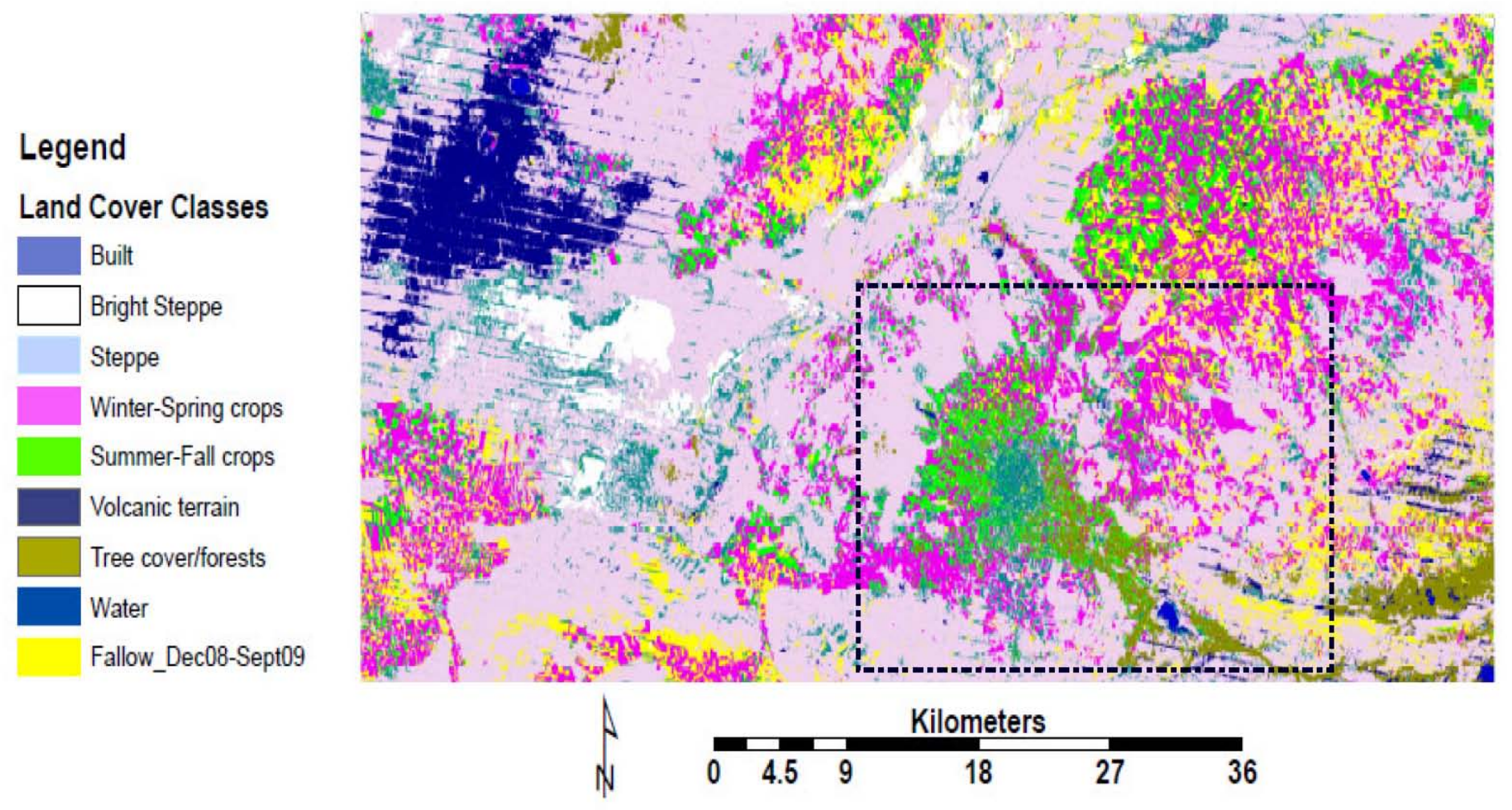
Observed classes

- Agriculture--High NIR (Dec, Apr, Jun)
- Agriculture--High NIR (Apr, Jun)
- Agriculture--High NIR (Jun)
- Agriculture--High NIR (Apr, Jun, Sep)
- Agriculture--High NIR (Jun, Sep)
- Agriculture--High NIR (Sep)
- Agriculture--Orchards/trees
- Agriculture--Fallow
- Steppe--High SWIR (1.65um)
- Steppe--Vegetation
- Steppe-Dark
- Steppe--Bright
- Mtn. Forests
- Built
- Volcanic regions
- Water

Combined classes (used in classification)

- Agriculture--"Winter-Spring" Crops
- Agriculture--"Summer-Fall" Crops
- Agriculture--Fallow
- Steppe
- Steppe--bright
- Forests/Ag. tree cover
- Built
- Volcanic regions
- Water

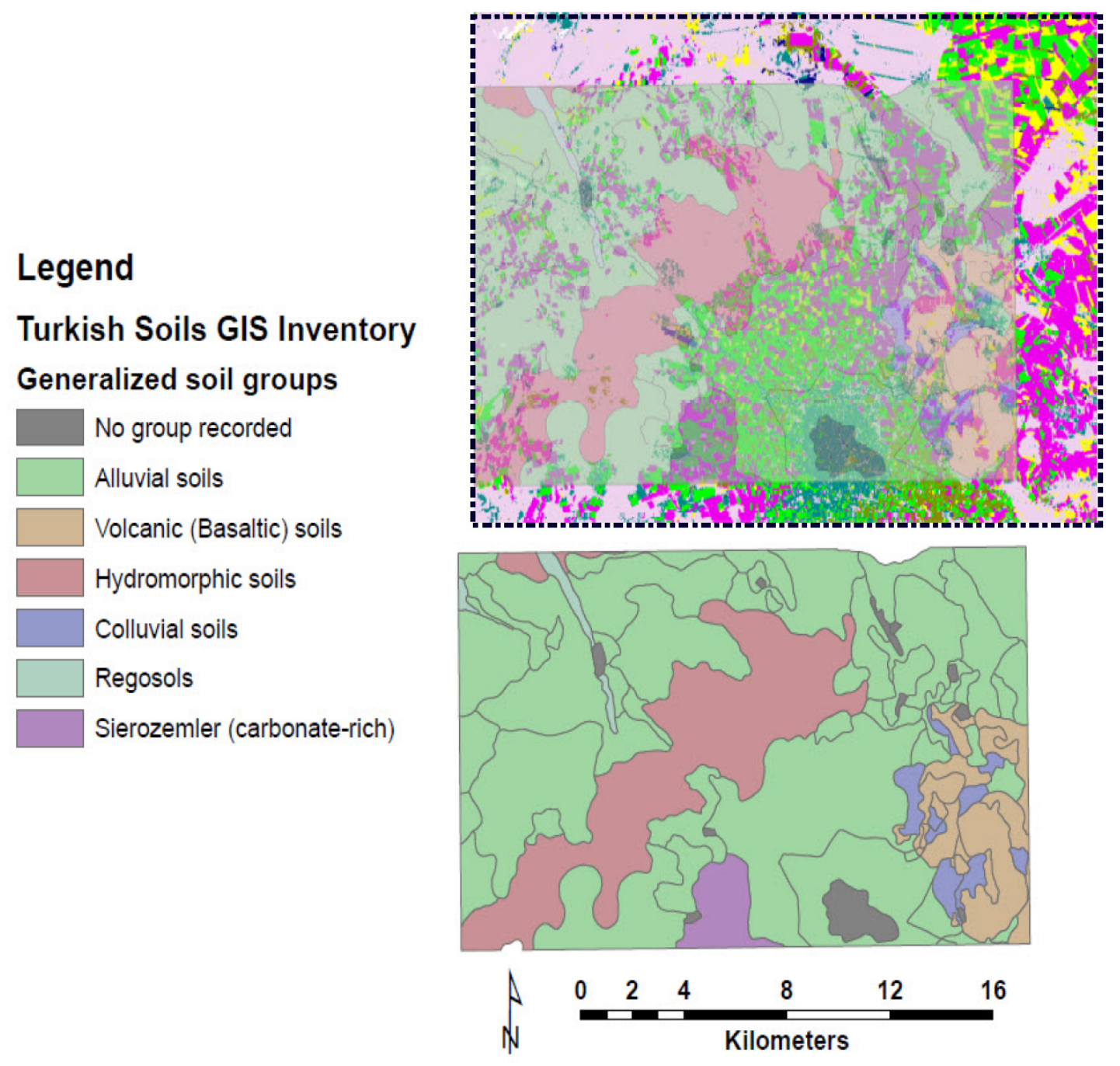
3. Classification: Experimentation with Machine-Learning and SVM algorithms



Draft classification result using the Support Vector Machine algorithm in ENVI (ITT). This is only a preliminary result, with a lot of noise due to the use of ETM+ data from 12/18/08 and 04/10/2009. and still-evolving land cover classes and training data. One goal of the project will be to compare the accuracies of decision-tree (C4.5) and support-vector machine (SVM) classification algorithms against ground-truth GPS points and other data, and use hierarchical classification methods such as those used by Pax-Lenny et al (1995). Working groups of land cover classes are listed below.

4. GIS-based analysis of land cover/use, physical and social variables for optimum selection of soil sampling sites

A subset of the draft land cover classification, combined with data on general soil groups from the Turkish Soils GIS inventory (right). We will use GIS to help plan a sampling scheme for soil organic carbon (SOC) and nitrogen (N) to be as representative as possible of landscape conditions, accounting for both natural and human-determined environmental parameters.



Assessing preliminary results

CONFUSION MATRIX FOR DRAFT MULTI-TEMPORAL LAND COVER CLASSIFICATION

*Time constraints prevented completion of a full accuracy assessment for this poster. This estimation below is a back-classification of training data, and is NOT a rigorous assessment, but rather a quick estimate to show what classes need further refinement.

Back-classified pixels (counts)

Class	Built	brightsteppe	steppe	spring crops	fallow	Volcanic	Forest	Water	Summer crops	Total
Built	26	0	4	0	2	0	0	0	0	32
brightsteppe	0	28	0	0	0	0	0	0	0	28
steppe	3	0	134	0	3	3	0	0	0	143
Ag_4_6	0	0	0	142	0	0	1	0	4	147
Fallow	0	0	3	0	35	1	0	0	0	39
Volcanic	1	0	3	0	0	37	0	0	0	41
Forest	0	0	3	0	0	0	34	0	0	37
Water	0	0	0	0	0	0	0	9	0	9
Ag_9	0	0	2	0	0	0	0	0	93	95
Total	30	28	149	142	40	41	35	9	97	571

Overall Accuracy = (538/571) 94.2207%
Kappa Coefficient = 0.9298

Class	Producer's Accuracy (Percent)	Producer's Accuracy Pixels)	User's Accuracy (Percent)	User's Accuracy (Pixels)
Built	86.67	26/30	81.25	26/32
brightsteppe	100	28/28	100	28/28
steppe	89.93	134/149	93.71	134/143
Ag_4_6	100	142/142	96.6	142/147
Fallow	87.5	35/40	89.74	35/39
Volcanic	90.24	37/41	90.24	37/41
Forest	97.14	34/35	91.89	34/37
Water	100	9/9	100	9/9
Ag_9	95.88	93/97	97.89	93/95

*NOTE: THIS IS NOT A TRUE ACCURACY ASSESSMENT,
IT IS BACK-CLASSIFICATION OF TRAINING DATA.
WE ARE STILL REFINING THE CLASSIFICATION.

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Land cover analysis challenges

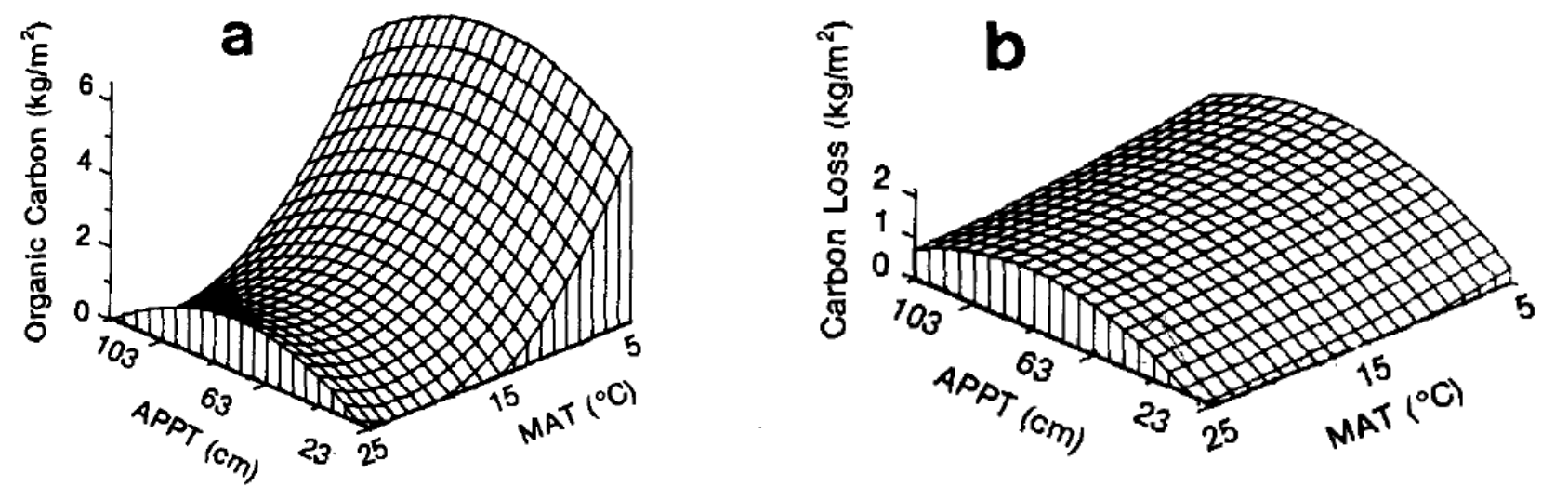
- **Choosing vegetation indices, data reduction methods improve classifications**
- **Maximizing user accuracy for land cover maps**
- **Differentiating irrigated versus non-irrigated crops reliably: do trends in phenology correspond with irrigation status?**
- **Differentiating areas of forest and forest re-growth from orchards along riverbanks**
- **Bright steppe: sand dunes, salt flats, or highly eroding regions? Significance for our analysis?**
- **Factoring changes in fertilizer use and cultivation practice into our analysis: asking good questions while doing fieldwork**

Impacts of agricultural intensification on soils, ecosystems

Cultivation and human land use affects all five soil formation factors (the CLORPTs):

- **CLimate: larger/altered soil seasonal temperature cycles, altered moisture regimes**
- **Organisms: changes in ecological conditions, species introductions/pests**
- **Relief: expansion of agriculture over steep topography can involve leveling, changing impacts on erosion**
- **Parent material: differential effects by location based on native soil textures, structures, underlying geology**
- **Time: “natural” rates of weathering, other processes greatly altered (often accelerated).**

Fig. 3. Predicted response surface of soil organic C to continuous, simultaneous variation in mean annual temperature and annual precipitation in range and cultivated soils for a set loam texture (20% clay, 40% silt).



Figures from: Burke, I.C. et al (1989). Texture, climate and cultivation effects on soil organic matter in US Grassland soils. *Soil Sci. Soc. Am J.* 53: 800-805.

Ongoing and future work

- **Complete independent accuracy assessment of current maps**
- **Translation of Turkish soil GIS information, further research on local soils, underlying geology**
- **Change-detection analysis for expansion of agricultural regions since late 1980s to inform soil sampling, study of relationships between expansion, irrigation and fallow land coverage**
- **Field work, Summer 2010**
    - **Ground-truth accuracy assessments of SVM, decision-tree land cover maps**
    - **Soil sampling**
    - **Talking with local farmers and managers about history, current practices, and challenges to sustainable land use**
- **Integrate results with studies of grain-scale soil physics and regional-global scale hydrological and biogeochemical models.**