

- (1) **Title of the Grant:** China's urbanization and its sustainability under future climate change
- (2) **Type of the report:** Second Year Progress Report
- (3) **Principal Investigator:** Peilei Fan
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1. Activities addressing objectives, findings, and main challenges:

Summary: In Year 2, we have accomplished Objective 1 as planned and worked on part of the Object 2 by continuing our data processing, conducting field surveys in Urumqi and Shanghai, analyzing linkages between urbanization, LULC, and climate change, and simulating future LULC and climate. In Year 3, we plan to accomplish the rest of Object 2, i.e., to finish simulations of LULC and climate change for different scenarios and to provide recommendations of adaptation strategies for the cities based on simulation results.

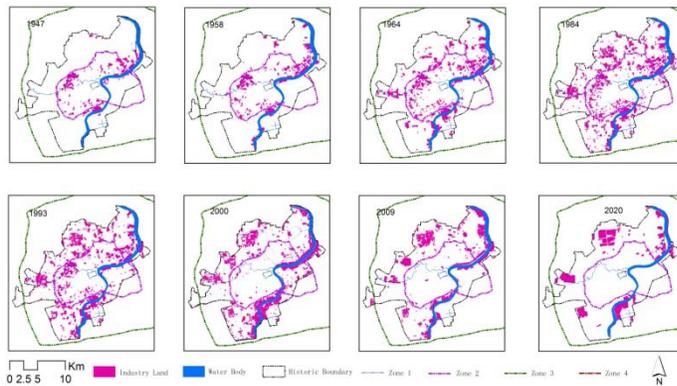
Objective 1. Linkage between urbanization, LULC, and climate change

- *Shanghai's urbanization, a sub-unit analysis*

We studied the spatial differentiation and the coupled development between the economy and the environment at the urban district level in Shanghai in the reform era. After evaluating the rapid expansion of the urban built-up areas of Shanghai, we, by using the Gini-Coefficient and the environmental Kuznets curve, analyzed the co-evolution of economic development and environment conditions to reveal the internal heterogeneity of the spatio-temporal evolution. **Findings:** We found that urban districts can be classified into either positive urbanization or negative urbanization districts. We identified the historical legacy, market oriented land reform, globalization, industrial restructuring, planning policies, and competition among district governments as the crucial driving forces for urban transformation and spatial differentiation in the Shanghai region.

- *Evolution of the urban land use in Shanghai, case of the industrial land*

Fig. 1. Industrial land use of Shanghai (1947-2020)



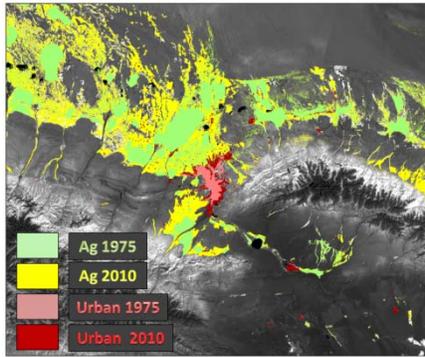
To gain a deeper understanding of Shanghai's urbanization and urban land expansion and restructuring, we examined the evolution of one type of the urban land use, industrial land, in detail. We evaluated the evolution of the industrial land in Shanghai since 1947 based on land use maps produced using aerial photo and satellite image interpretation techniques and combined with field surveys. **Findings:** We found that Shanghai's industrial land has transformed from a hybrid mono-centric pattern to a specialized poly-centric pattern as Shanghai's industries increasingly locate/relocate to the suburbs, especially during recent decades

(Fig. 1). By using a binary spatial logistic regression, we found that major spatial determinants contributing to the conversion of Shanghai's industrial land include distance to transportation routes and planning policies such as industrial zones (re)creation and directed inner city redevelopment.

- *Develop LULC maps for Urumqi focusing on Agriculture & Urban Expansion*

We focused on developing Landsat classifications for 1975 and 2000; and a 2010 classification map developed by integrating Landsat TM and PALSAR fine-beam imagery, with a focus on agriculture and urban for model parameterization. In the first classification phase we used a Classification and Regression Tree approach developed in Python that relies on randomForest and rpart libraries in the R software package. The second classification phase was carried out during post processing by executing operational thresholding of Landsat reflectance indices, PALSAR sigma nought values, and an ASTER DEM. **Challenges:** The geopolitical climate in Urumqi limited the ability to obtain georeferenced field data. We overcame this project challenge by collaborating with colleagues at Xinjiang University who graciously shared a limited set of year 2000 GIS vector files, which we supplemented by

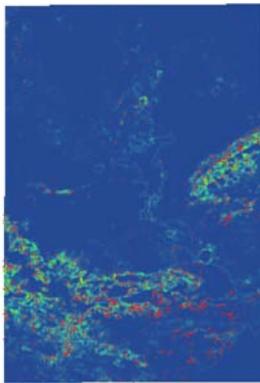
using Google Earth as calibration and validation data. Technical challenges included the lack of multitemporal



imagery and poor quality signal-to-noise ratio for 1975 imagery compared to the 2000 and 2010 Landsat data. We overcame this challenge by using the iterative post classification approach to systematically remove or reduced misclassifications. **Results** show the location and rate of change for agriculture and urban land uses between 1975, 2000, and 2010. Between 1975 and 2010 agriculture and urban expanded by 47% and 33%, respectively (Fig. 2). In 1975 there was 4257 km² of agriculture and 177 km² of “core city” urban and in 2010 there was 8963 km² of agriculture and 533 km² of urban. We also compiled a transition matrix to illustrate the land use changes.

<=Fig. 2. Classification products highlight growth in agricultural and urban classes, both of which nearly doubled between 1975 and 2010.

- **Uncertainty model for MODIS land cover type product**

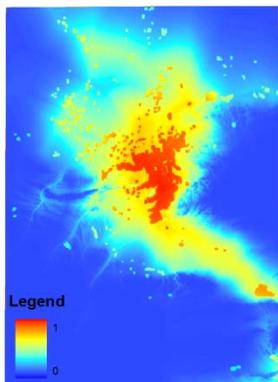


<=Fig. 3. A logit based prediction of uncertainty for the Urumqi region. Note: Areas in red are both predicted to be uncertain and, in our control MODIS data sets, present high levels of land cover confusion.

The MODIS Land Cover Type (MLCT) dataset is a widely used satellite-data derived global land cover dataset. MLCT products are available beginning from 2001, and in the most recent iteration “Collection 5” the spatial resolution was changed to 500m. **Challenges:** MLCT products are increasingly used in regional climate modeling activities but data quality remains a significant concern. Although the overall accuracy of MLCT products is claimed to be about 75%, it is much lower for certain land cover classes and in certain regions. The impact of this uncertainty on applications is still unclear. **Main outcome:** We have developed an uncertainty model from the time series of MLCT products for the Urumqi study area (Fig. 3).

Both spatial and categorical uncertainties were uncovered by examining changing pixel trajectories. In order to study the propagation of those “uncertain” features in land cover, dozens of alternative land cover realizations have produced using an uncertainty model. **Current work and future plan:** These realizations are currently being used to model regional climate in RAMS via a dynamical downscaling approach. The incredibly intensive computing requirement for these dynamic climate processes requires many months of simulation/computer time.

Objective 2. Simulation of future LULC and regional climate changes, impact of climate change, and adaption and mitigation strategies



- **2a Simulation of current and future LULC**

Dyna-CLUE, the most recent version of the Conversion of Land Use and its Effects (CLUE) model, is a modeling framework to simulate land use change using empirically quantified relations between land use and its driving factors in combination with dynamic modeling of competition between land use types. The current version is able to deal with dynamic driving factors and includes autonomous developments through bottom-up simulation. Simulation activities have centered on the patterns and processes of urban expansion (Fig. 4).

<=Fig. 4. Urban Suitability map combining driving factors and neighborhood effect

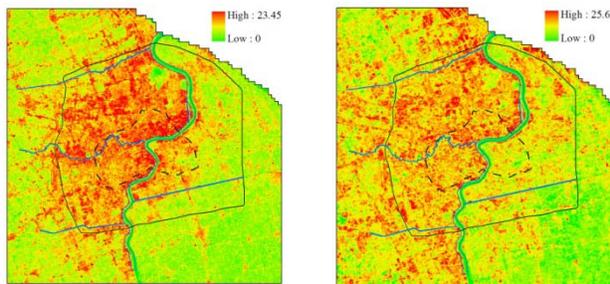
Current work and future plan: A logistic model has been developed that included neighborhood effects, to establish the relations between hypothesized driving factors and urban land uses. Parameters were established and calibrated using land cover maps of 2000 and 2010. Future scenarios of urban expansion will be simulated and added to RAMS. For instance, for Shanghai’s LULC simulation, the planning document is considered as a reference of total amount for each future LULC types. Five geo-coded LULC types, built-up, agriculture, forest, industry, and other are extracted for simulation. Input driving factors include demographic data, such as population density at neighborhood level, revenue per capita at district level; and geographic data, such as distance to Central Business District area (CBD) and distance to main roads; as well as economic data like Foreign Direct Investment (FDI) data at district level.

- **2b Regional climate simulation under IPCC scenarios**

In terms of climate analysis due to changing land cover distributions, several regional climate model (RCM) simulations are underway. In the Urumqi area, we are investigating potential changes in land cover (particularly degradation) on overall atmospheric dynamics—convection, wind speed, rainfall, and near-surface humidity. These simulations, at 2 km resolution, are expected to test whether or not recent trends in land cover change will act to suppress growing-season rainfall or not. Of additional interest is the question of how urban expansion will affect these variables under climate change, and we are debugging simulations in order to project these impacts out to 2050. **Challenges:** There have been some problems with numerical stability in the RAMS code, and we are working to resolve this. Error propagation from land cover parameterizations is also a major undertaking using the RCM that has just been begun. 64 maps of Urumqi land cover have been imported into RAMS and are being simulated at a 2 km grid spacing. These simulations are expected to be complete in July. Statistical downscaling using the same methodology as Worldclim was also applied to future data. To make some independent estimates of future climate trends, we categorized the landscape into either “green” or “impervious” and removed LST data for those pixels. To look at a range of changes in extreme hot days, we extracted the temperature distributions for impervious pixels and added Gaussian noise to the distribution.

- **2c Impact of climate change on cities & 2d Adaptation and mitigation strategies**

Urban Heat Island in Shanghai



<= Fig. 5. Shanghai’s urban thermal environment (unit: °C) (L: 2000, R: 2008)

We have reviewed the historical climate records of Shanghai, based on Xuhui station’s meteorological data. Overall, Shanghai’s annual average temperature has an increasing trend over the last century; summer and winter both in generally became hotter from 1949 to 2009. We select urban heat island, a representative

of extreme events, to study Objectives 2c & 2d. We quantified the impact of human activities on the spatial pattern of the urban thermal environment in Shanghai. Based on thermal remote sensing and GIS spatial analysis, we analyzed the spatial pattern and generation of the urban heat island in Shanghai city from 2000 to 2008 (Fig.5). We then investigated factors contributing to the urban heat island employing Principal Components Analysis (PCA). **Findings:** We found that land surface modification, landscape configuration and anthropogenic heat release have been the leading factors contributing to the urban thermal environment in Shanghai city. We also constructed a linear model including these three components to simulate the spatial pattern of the urban heat island. This model, which results in a significant correlation coefficient between the simulated and real land surface temperature, is useful to simulate the influences of human activities on thermal environment and thus help decision makers plan to adapt and mitigate urban heat island effects in Shanghai. Our study confirms the positive outcome from the mitigation effort by the municipal government of Shanghai in increasing the green coverage to lower temperature and decrease urban heat island intensity in the city core.

2. Publications and Presentations/Posters at Conferences

- Fan P, Yue W, Huang H, Messina J, Qi J, Verburg Q, Moore N, Ge J. (submission 2011). Forward to a post-industrial city? The evolution of the urban industrial land in Shanghai. *Landscape and Urban Planning*.
- Li X, Messina J, Fan P, Moore N, Shortridge A. (submission 2011) Propagation of Land Cover Uncertainty in Climate Simulations. *Environmental Research Letters*.
- Yue W, Liu Y, Fan P, Xu J. (submission 2011) Quantifying the impact of human activities on spatial pattern of the urban thermal environment: a case study of Shanghai. *International Journal of Health Geographics*.
- Fan P. 2010. “Forward to a post-industrial city? The evolution of the urban industrial land in Shanghai.” Global Land Project 2010 Open Science Meeting (Tempe, AZ). 2010. Presenter (October 17, 2010)
- Li, Xue and Messina, Joseph. 2010. “Spatial error structures of MODIS land cover map products for Urumqi, China”. East Lakes Regional Division Meeting of AAG (Grand Rapids, MI). Poster (October 22/23, 2010)
- Yue W. 2010. “Spatial Differentiation and the Coupled Development of Economy and Environment of Shanghai” Association of American Geographers Conference (Washington DC). Presenter (April 17, 2010)

Fan P. "Rising new centers in globalizing cities: a case of Pudong New Area in Shanghai." Association of American Geographers (AAG) Annual Conference (Washington DC). Presenter (April 16, 2010)