地理研究 第 75 期 民國 111 年 05 月
Journal of Geographical Research No.75, May 2022
DOI: 10.6234/JGR.202205_(75).0001

Geography Engaged: Spatial and Temporal Dimensions of the Land Tenure-Ecosystem Services Feedback Loop

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Abstract

This article is a nominally edited transcript of the conference presentation of the same name from the IGCT-GSCT Joint Conference 2020 held in Taipei on November 17, 2020. The goal was to link ideals that resulted from the 2005 Millennium Ecosystem Assessment (MEA) Project to field-based human-environment geographic research. Using a case study of land use/land cover (LU/LC) change in the Jiangning District of Nanjing, China during the years from 2000 to 2015, this article highlights the potential application of commonly used geographic techniques such as geographic information systems (GIS) and remote sensing for ecosystem assessment research. Developing effective assessment methods, at appropriate scales of analysis, is foundational to progress in applications of these cascading (nested) Ecosystem Services Assessment (ESA) or Millennium Assessment (MA) models. The ESA paradigm is dynamic over both time and space and underscores the potential of combining spatial-temporal GIS and remotely-sensed data with developing ESA models such as those imagined by the United Nations Millennium Assessment program. The article emphasizes the important contributions that can be made by linking GIScience to ecosystem services assessment research, while also illustrating the disconnects between available data, and the inadequate use of data, to generate holistic studies required for comprehensive MA model development.

Keywords: Ecosytem Services Assessment, Millennium Ecosystem Assessment, GIScience

Introduction

The Millennium Ecosystem Assessment project or MA (www.MAweb.org) was initiated subsequent to comments made by then UN Secretary-General Kofi Annan in his 2000 report to the UN General Assembly that summarized his vision for the many roles that the United Nations should play in the 21^{st} century. Much of his speech centered on the necessity of the United Nations taking a leadership role in environmental research with a focus on greater understanding of the feedback between humans and their environments.

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More than 2000 international researchers and reviewers took part in the massive project coordinated by the United Nations Environment Program that sought to "assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being" (Millennium Ecosystem Assessment, 2005: Preface). The four working group reports (Condition and Trends, Scenarios, Responses, and Sub-global Assessments) as well as the general summary, Ecosystems and Human Well-being: Synthesis, were all published by 2005, and since then, countless researchers from diverse disciplines have integrated elements of these reports and MA-defined goals in their work. Most generally, "the conceptual framework for the MA posits that people are integral parts of ecosystems and that a dynamic interaction exists between them and other parts of ecosystems, with the changing human condition driving, both directly and indirectly, changes in ecosystems and thereby causing changes in human well-being" (Millennium Ecosystem Assessment, 2005: Preface).

The logic of aspirations such as those quoted above is readily apparent to all attending this conference, and indeed to the vast majority of researchers concerned about human-environment interactions, but especially for those in the discipline of Geography. Long ago, the seminal essay by William D. Pattison first presented at the opening session of the annual convention of the [US] National Council for Geographic Education, in Columbus, Ohio, on November 29, 1963 included human-environment relations as one of the four enduring themes of the discipline (Pattison, 1964). Pattison's essay is still read by almost all geography students in the United States.

There are many excellent summaries or reviews of the MA vision that informed our work, including those by Carpenter *et al.* (2009), Fedele *et al.* (2017), and Small *et al.* (2017), as well as a 2016 applied study by Li *et al.* (2016) focused on Nanjing. What follows as the remains of the introduction has a specific focus on MA findings related to the issues and challenges of data collection and analyses needed to advance the MA agenda. On the 20 anniversaries of the inception of the UN MA program, it is useful to consider what if any contributions should/could geographers make towards this comprehensive effort. There is a massive amount of literature on the topic of environmental assessment, and even for a monumental effort as the Millennium Ecosystem Assessment program, it is easy to lose this particular tree in the endless forest. Still, it would be a shame if we collectively forgot the UN MA program simply because it is now entering middle age, and perhaps the challenge seems too great to be addressed in our own scholarship.

One of the sections of the Synthesis volume of the Ecosystems and Human Well-Being report that was most influential to me concerned the "most important uncertainties hindering decision making concerning ecosystems" (Millennium Ecosystem Assessment, 2005:101-102). Essentially, this section identified data bottlenecks and missing data. The MA report provides a list of concerns that the authors felt must be addressed at multiple scales, (global, regional, local) if more synthetic and useful environmental assessment can be completed and converted into policy initiatives. "The MA was unable to provide adequate scientific information to answer a number of important policy questions related to ecosystem services and human well-being. In some cases, the scientific information may well exist already, but the process used and the time frame available prevented either access to the needed information or its assessment" (Millennium Ecosystem Assessment, 2005:101). Cascading EA models (think global climate models or GCM), remotely-sensed data collection and analyses, GIS, Big Data Analytics, Unmanned Aerial Vehicles (UAV), and geovisualization techniques are all mentioned in summary and sub-reports, as being used, or as having potential to further MA goals. In reading these reports, I realized that often the goals of comprehensive environmental assessment are often quite similar to the goals of human-environment relations research in geography. Further, many of the technical skills mentioned as lacking in much international EA research are commonly included in the training of any undergraduate/MS/PhD student in geography. Geography has the tools, but perhaps needs to commit more thought, time and effort to considering how the MA vision might influence geographic research. That is the broadest goal of this presentation.

As a geographer, it is hard not to notice that while much use is made in the MA reports of techniques originating in our discipline such as remote sensing of the environment and GIS multi-dimensional/ multi scalar temporal analyses, there is scant mention of "Geography" in the MA reports. Our discipline, so well-suited to serve at the nexus of MA-inspired research was not really seated at the UN "table" stocked with environmental researchers, sociologists, anthropologists, biologists, soil scientists, chemists, meteorologists, climatologists, and many others. The more I have incorporated the ideals and goals of the Millennium Ecosystem Assessment in my teaching and research, the more I have wondered why this is the case. Geography, as the most synthetic of all academic disciplines, could well serve as the glue that binds all the parts, but it is not (Clifford *et al.*, 2016). I do not wish to encourage defensiveness, or complain about why geography is often overlooked by MA research teams, rather I would like to look at why this might occur. It is definitely not the topic. Virtually all major content themes of the MA are central to geographic research. Many of the techniques employed are central to the discipline, and the concept of the time-space continuum, measuring change over different scales both temporally and regionally is imbedded one way or another in many of our research and teaching efforts.

Perhaps the places we publish are not commonly recognized? It is true that the impact factors of most geography journals are relatively low, and citations by non-geographers are often limited. This could mean that few environmentalists outside the discipline discover enough of our more effective efforts to appreciate the potential of the holistic tradition in geography. It is true geographers are almost always working, and referencing, across disciplines, more than scholars in other disciplines, but I think better promotion, which would require publishing in journals of other disciplines, while emphasizing the "Geographers art", is only part of the problem. Increasingly, I have decided that the lack of access and/or visibility are really only symptoms.

I think the major issue, not so easily addressed, is that despite our claims that geography is THE synthetic discipline, we do not really regularly publish synthetic research incorporating a rich combination of environmental and human dimensions on a regular basis in leading environmental journals. When I was kindly invited to participate in this conference last summer, this issue was one I was thinking about (and we were talking about) in my graduate research methods class at Western Michigan University. How do we develop comprehensive research projects that do not just “talk the holistic talk’ but also “walk the holistic walk”? That is, how should we design research so that it really is “holistic”, synthetic, or “cross disciplinary” (Archer, 1995; Harvey, 1997)? How should geography and geographers invest in projects that really focus on the identification and analyses of complex human environment relations such as those formulated in the Millennium Ecosystem Assessment program?

Because of the breadth of our discipline, and the unique intersections between our research methods and topics, generalized or universal goals and aspirations seemed too vague for this presentation. I worried that by giving a lecture centered on the fundamentals of the original MA vision, I would simply be re-stating the goals, adding little that was new; more like a very supportive book review of Ecosystems and Human Well-Being than original work. After thinking about this for several months, I ultimately decided my own thoughts would gain focus from a critique of the project that I was working on at the time I received the initial invitation to present a keynote address to the November 17, 2020 IGCT-GSCT annual conference. I decided to re-evaluate just-completed research we conducted in Jiangning, Nanjing, Jiangsu from the first grant proposals to the final publications to see what I thought we did properly, and where we failed. The comments that follow is NOT a presentation of the research project and outcomes which published elsewhere (Veeck *et al.*, 2020). Rather, I want to use the Jiangjing LU/LC project as a case study to illustrate how the ideals of the MA vision might be applied to human-environment field research in geography.

A brief description of the case study of agricultural land use change in Jiangning District, Nanjing from 2000 to 2016.

The case study I wish to use, providing both positive and negative examples of potential holistic MA-influenced research is a recently project developed by myself, my friend, colleague and frequent co-researcher, Charles [Jay] Emerson, and graduate student Erik Breidinger of Western Michigan during the period from 2017 to 2019 focused on the Jiangning District of Nanjing, the capital of Jiangsu Province, PRC (Breidinger, 2019; Veeck *et al.*, 2020). All participated in fieldwork, so we were familiar with what was actually “happening on the ground”. Fieldwork is essential to our craft. The GIS and statistical units of analyses in the study were the ten jiedao, or sub-district administrative units of Jiangning annually for the period from 2000 to 2015 (Figure 1).

Figure 1 Location of Jiangning District in Nanjing, Jiangsu

Source: Cartography by Jason Glatz, WMU Waldo Library, Design by Gregory Veeck.

The applied portion of the research to be discussed in detail directly, was linked to a theoretical debate regarding the permanence of arable land identified as a characteristic of the Desakota Model first put forward by Terry McGee, Norton Ginsburg and others in the late 1980s. A summary of this theoretical model is not the focus of this essay or presentation so I refer the audience to seminal essays by Ginsburg (1991), McGee (1989), McGee (1991) and Zhou (1991) to discover its origins. But basically, supporters of the “desakota” model, first put forward by Terry McGee and Norton Ginsburg believe that at least for the time being, large Asian cities form differently and have different components in different proportions compared to those that informed the Eurocentric theoretical view of cities that evolved in the west. For some idea of how this model has been applied in more contemporary studies of Asian urbanization, including one for Taiwan, I suggest Chen *et al.* (2016b), Sui and Zeng (2001), Winarso *et al.* (2015), Wu and Sui (2016), and Xie *et al.* (2006). There are many elements to the “desakota” model, but central to this presentation and essay is the important debate, within the desakota model literature, centered on the continued permanence of agriculture within desakota districts, despite great LU/LC pressures associated with many aspects of urbanization (Ginsburg, 1991; Latz, 1991; McGee, 1989).

Today, however, I wish to focus on the data types and sources for the project, how these data were used, and as importantly, how they were not used, but perhaps could have been so as to stimulate thoughts on how we, as geographers, might design our own projects to create more comprehensive, and ultimately more successful, MA-inspired holistic research efforts.

The mixed methods project was based on interviews with migrant farmers during two summer site visits (2017, 2018) combined with time-series land cover/land use (LC/LU) analyses of a project-developed GIS database combining annual agricultural and agro-economic data from the Jiangning Statistical Yearbooks published by the Nanjing City Jiangning District Statistical Bureau for 2001, 2011, 2015, and 2016 for the period from 2000 to 2015 and LU/LC data layers derived from growing season satellite imagery including Landsat 8 Operational Land Imager (OLI) and Landsat 5 Thematic Mapper (TM) imagery. Once funding was received, land cover maps were created using 30m2 resolution Landsat imagery (Worldwide Reference System Path 120 Row 38) for dates within the May –October growing season contingent on minimal cloud cover so as to independently estimate annual changes in LU/LC and specifically identify changes to agricultural land stocks. With higher resolution data, Breidinger (2019) then focused on developing a means for measuring PVC greenhouse area which is usually white (black for mushrooms), and often misclassified as urban or built-up land. After he developed his method, adjustments were made to generate the time-series LU/LC maps with the 2015 LU/LC map, by way of example, as Figure 2. The estimates of land cover change by category for 2000, 2010, and 2015 are reported in Table 1, and the Kappa coefficients and values are reported as Table 2. Conveniently, each Landsat image covers the entirety of Nanjing City, so to expedite data processing in the ENVITM image analysis application, a mask was applied so that only reflectance values for the ten jiedao, the units for analyses for the project, within the Jiangning District were analyzed. While the data were analyzed for research purposes using unsupervised, supervised and object-trained methods, ultimately our final absolute area and proportional estimates of land cover, were derived from object-trained supervised maximum likelihood classifications. Our subsequent analyses investigated agricultural land cover supported with training point data collected during field visits and cross-checked using latitude and longitude point data selected for multiple years from Google Earth Pro (https://www.google.com/earth/versions/). Four land cover classes were used in this analysis: Built-up land, Water bodies, Forest land, and Agricultural land. Once each pixel was assigned to a land cover type, absolute area and proportions (%) for each land cover type within each jiedao were estimated for each year of the study. These data were combined in our GIS with archived statistical data related to crop production by type, crop area, and many other typical agro-economic and socio-economic variables aggregated to the ten jiedao units of analysis, the smallest administrative unit with available published historical data.

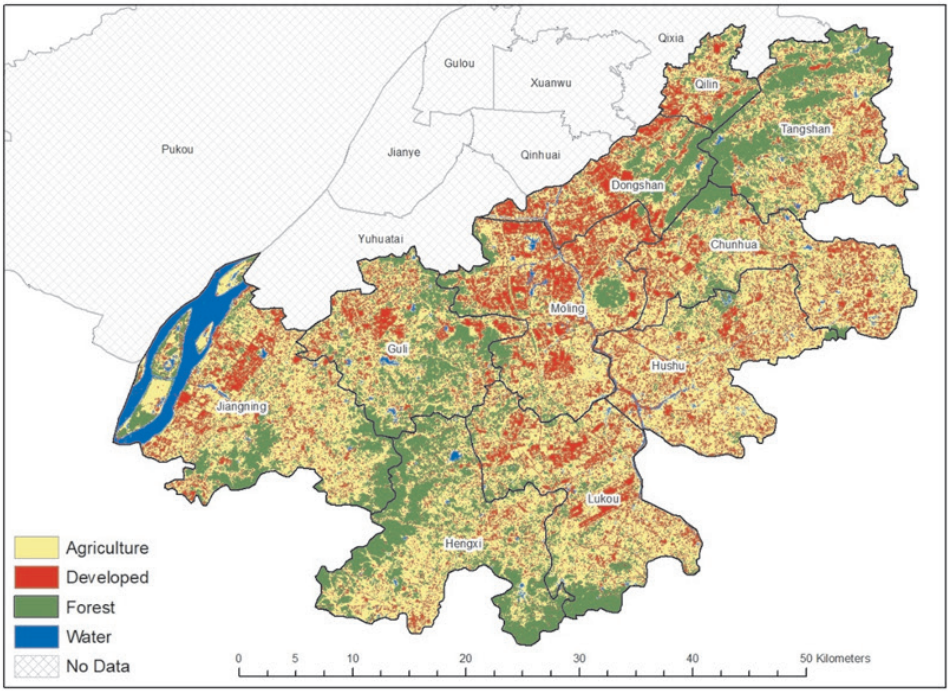

Figure 2 Supervised Classification 2015

Source: Veeck *et al.* (2020); Breidinger (2019).

Table 1 Object-Trained Supervised Per Pixel Land Cover Classification in Percent: 2000 - 2015

Land Cover	2000	2010	2015
Agricultural Land	78%	55%	52%
Developed Land	8%	28%	26%
Forested Land	11%	14%	19%
Surface Water	3%	3%	3%

Source: Veeck *et al.* (2020); Breidinger (2019).

Table 2 Object-Trained Supervised Per-Pixel Land Classification Kappa Coefficients: 2000 - 2015

2000	Agriculture	Developed	Forested	Water	Totals	Kappa
Agriculture	23	5	0	2	30	.52
Developed	9	20	1	0	30	
Forested	1	0	28	1	30	
Water	0	8	1	21	30	
Total	33	33	30	24	120	

2010	Agriculture	Developed	Forested	Water	Totals	Kappa
Agriculture	25	5	0	0	30	.65
Developed	1	25	0	4	30	
Forested	1	0	29	0	30	
Water	0	1	0	29	30	
Total	27	33	29	33	120	
2015	**Agriculture**	**Developed**	**Forested**	**Water**	**Totals**	**Kappa**
Agriculture	22	6	2	0	30	.57
Developed	13	17	0	0	30	
Forested	1	0	29	0	30	
Water	0	1	0	29	30	
Total	35	24	29	29	120	

Source: Veeck *et al.* (2020).

As originally planned, an edited version of the 2014 map of Jiangning district published by China IPPR International Engineering Corporation in conjunction with IPPR International Nanjing Urban Planning and Architecture Design Institute served as the base map for our analyses. This was edited to conform to the changing jiedao boundaries over the years from 2000 to 2020. Locating these historic maps was a challenge, but date correction via aggregation of the declining number of jiedao was accomplished, and subsequently all archived statistical data for the years from 2000 to 2015 were adjusted so as to allow assessment of change over time for the current jiedao boundaries. The Jiangning statistical yearbooks were all purchased from a commercial on-line book seller. Ultimately, for our publications, only data and results for the years 2000, 2010, and 2015 were presented, excepting for the regression analysis which also incorporates data from 2014 to adequately meet sample size requirements.

The yearbooks provide a variety of demographic and agriculture-related variables at the jiedao scale. Based on this archived official data, a time series data set for 2000, 2010 and 2015 was created in SPSS 25.0 so as to compare diagnostic variables related to agricultural production and agricultural permanence over time. Triangulation comparing the LU/LC estimates derived from analyses of the Landsat images with the published data provided in the Jiangning Statistical Yearbooks indicate our estimates are accurate, once greenhouse areas were included, with only slight variations for 2000 and 2010. There was a slightly greater deviation between image-derived LU/LC and the archived data for 2015 (4.33% difference in estimates), which we credit to the smaller arable land parcel size in 2015 which resulted in misclassification when parcels were too small to accurately categorize (Table 3).

Table 3 A comparison of official statistical yearbook estimates for arable land and those derived from an object-trained supervised maximum likelihood (ML) land cover classification for the ten *jiedao* of Jiangning District of Nanjing for 2000, 2010 and 2015

jiedao (Sub-district)	Archived Statistical estimates of arable land 2000	ML estimate of agricultural land cover 2000	Difference between yearbook statistics and ML estimate 2000	Archived Statistical estimates of arable land 2010	ML estimate of agricultural land cover 2010	Difference between yearbook statistics and ML estimate 2010	Archived Statistical estimates of arable land 2015	ML estimate of agricultural land cover 2015	Difference between yearbook statistics and ML estimate 2015
1	2	3	4	5	6	7	8	9	10
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Dongshan	65.2	63.2	2	33.03	36.6	-3.57	39.91	38.6	1.31
Moling	77.22	77.1	0.12	38.25	40.86	-2.61	49.04	45.2	3.84
Tangshan	66.54	66.6	-0.06	48.56	45.9	2.66	47.15	43.1	4.05
Chunhua	91.55	90.7	0.85	64.95	58.5	6.45	58.21	52.4	5.81
Lukou	84.77	84.8	-0.03	58.11	52.4	5.71	56.56	48.6	7.96
Jiangning	67.33	65.8	1.53	46.79	46.2	0.59	48.46	44.3	4.16
Guli	79.88	80.7	-0.82	59.91	53.0	6.91	45.33	43.2	2.13
Hushu	94.04	93.9	0.14	64.42	56.0	8.42	64.73	55.7	9.03
Hengxi	72.05	72.8	-0.75	67.91	58.8	9.11	48.67	43.0	5.67
Qilin	77.55	75.9	1.65	47.78	43	4.78	43.19	43.6	-0.41
Jiangning District	77.613	77.2	0.413	52.971	49.1	3.871	50.125	45.8	4.325

Sources: Archived data from Nanjing City Jiangning District Statistical Bureau (2001: 47-76; Chapter 32011: 43-60; Chapter 4, 2016: 48-67, Chapter), and Nanjing Statistical Yearbooks 2001, 2011 and 2016. Maximum Likelihood agricultural land estimates calculated by authors based on 2000, 2010 (Landsat 5) and 2015 (Landsat 8) images

The city of Nanjing in Eastern China was selected for the study for many reasons. I conducted agricultural land use and crop production surveys in Jiangning [then a county within Nanjing prefecture] in 1987 and was quite familiar with the area and the most common traditional crops and cropping systems employed by farmers in the district at that time. Further, I visited Jiangning regularly from 1987 to the present, met with land use planners in 1987, and at other times over the years. Through my visits, I experienced the agricultural transformation that was occurring, as well as the effects of massive “land grabs” by diverse actors for the expansion of housing, transport, manufacturing and tourism (Jiangning Xian Nongye Qu Hua Bangongshi, 1983; Veeck, 1988).

Jiangning, a recently incorporated district of Nanjing, seemed like an ideal location to study agricultural land change within a desakota region as a representative example of urbanization trends for Chinese cities for this period. The city is also an excellent candidate for a case study as scholars report that Nanjing is quite representative of contemporary growth patterns of large extended metropolitan regions throughout China and Asia (Luo and Wei, 2006; Sui and Zeng, 2001; Xu *et al.*, 2007; Xu *et al.*, 2010). Further, after 2001, urban Nanjing changed from what Chen *et al.* (2016b) describe as a mononuclear city to a polycentric city (Luo and Wei, 2009), putting great pressure on available land, including arable land (Chen *et al.*, 2016a; Nanjing Statistical Yearbook, 2016; Veeck *et al.*, 2015).

Our findings presented as Figures 3 and 4 indicate that Jiangning continues to retain high, if decreasing, proportions of agricultural land and employment, while farm-related revenues (GDP) and per capita rural incomes are at an all- time high, adjusted for inflation. After significant decreases for all ten jiedao from 2000 to 2010, conservation policies appear to have helped slow and stabilize arable land losses from 2010 to 2015 as indicated by the change in slopes that can be observed after 2010 on Figure 5. However, those jiedao in closest proximity to Nanjing's central business districts lost arable land at greater rates than those in the periphery, interestingly representative of the seminal work of Johann Heinrich von Thünen (O'Kelly and Bryan, 1996). As is always the case regarding LU/LC in mainland China, the government plays a central role in Jiangning as well (Shen and Shen, 2017). OLS linear multiple regression analyses identified factors that are the most effective predictors of arable land persistence including: lower mean wages, higher percentages of men in the workforce, a greater reliance on traditional double-cropped rice-wheat, and (inversely) to vegetable production. The actual regression model and related discussion may be found in Veeck *et al.* (2020).

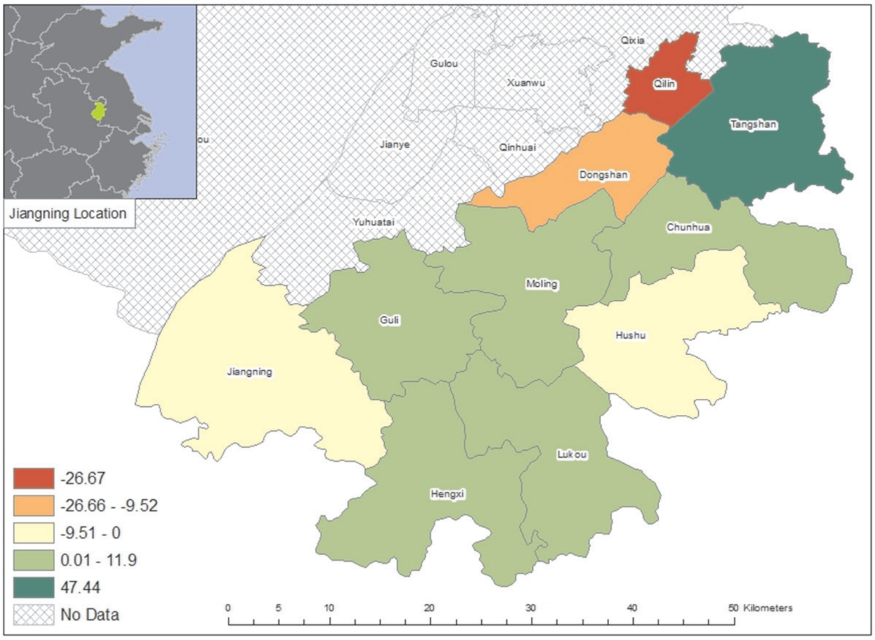

Figure 3 Percentage change in agricultural GDP, adjusted for inflation, for Jiangning District, Nanjing, Jiangsu from 2000 to 2015

Source: Calculated by author.

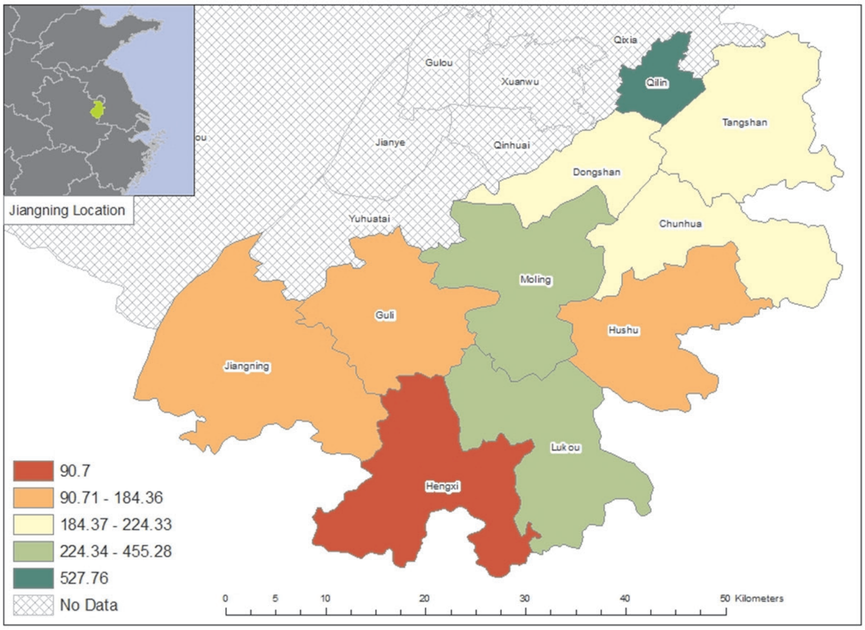

Figure 4 Percentage change in per capita rural income for Jiangning District, Jiangsu: 2000 – 2015

Source: Calculated by author.

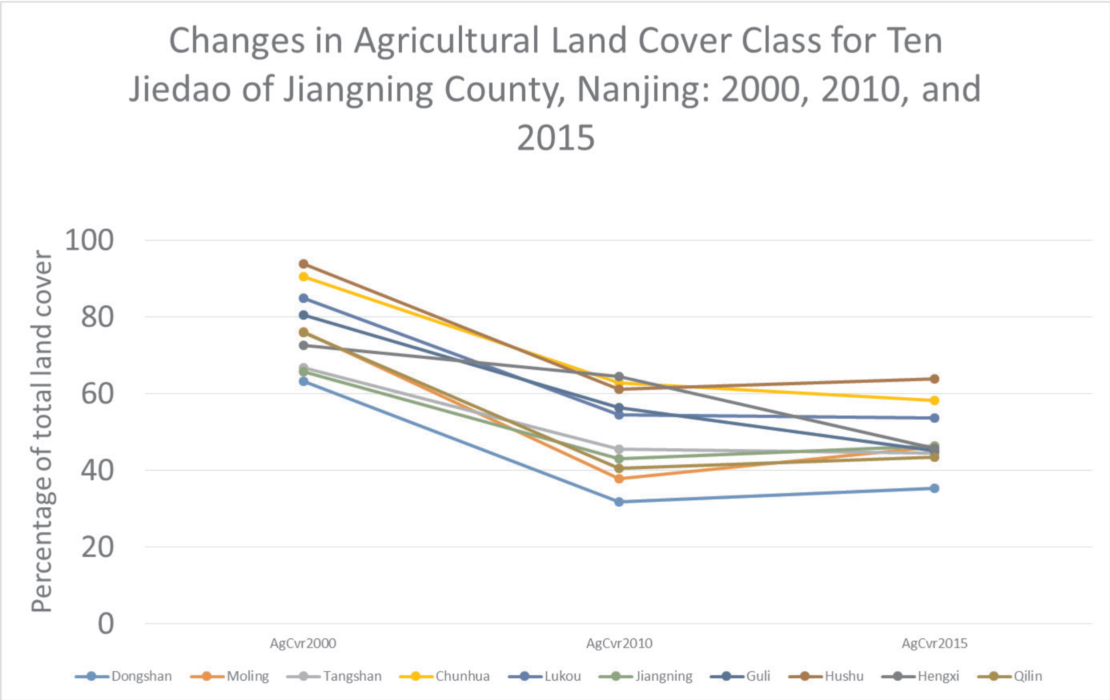

Figure 5 Changes in arable land stocks for 10 *jiedao* of Jiangning District, Nanjing, Jiangsu: 2000, 2010 and 2015

Source: Calculated by author.

What we found out in the Jiangning LULC study

During and after the research, numerous presentations of our results were made in both China and the US, and to date there are two publications based on our fieldwork and imagery analyses (Breidinger, 2019; Veeck *et al.*, 2020). In the information dissemination stage, we were able to draw attention to declining arable land in Jiangning, support the legitimacy of the Desakota model for Asian cities, and raise questions about current land preservation efforts based on comparisons of archived data and independently derived analyses of remotely sensed data at multiple scales. We joined these environmental results to changes in socio-economic conditions including gross production and changes to production for each jiedao from 2000 to 2015 for the ten major crops (or crop categories for fruits and vegetables) produced in Jiangning. This allowed us to assess the overall health of the farm sector in Jiangning, which we found to be remarkably good, despite very difficult conditions and rapid arable land loss.

Specifically, as reported in Tables 4 and 5 showing changes in crop area and production, and supported by our interviews, there are good reasons for these shifts in farm land use such as declines in profits associated with grain production and increases in profits for organic tea (Longjing), fruits, vegetables and fish, crabs, shrimp and crayfish.

Table 4 Changes in production of major agricultural commodities in Jiangning: selected years

Commodity	Units	2000	2010	% change 2000 to 2010	2015	% change 2010 to 2015
All Grain	tons	325,663	229,293	-29.6	234,166	2.1
Rice	tons	278,098	190,027	-31.7	185,476	-2.4
Wheat	tons	14,424	22,361	55.0	36,527	63.4
Peanuts	tons	1,804	1,183	-34.4	1,013	-14.4
Sesame	tons	2,231	1,202	-46.1	1,081	-10.1
Rapeseed	tons	62,899	24,498	-61.1	17,615	-28.1
Vegetables	tons	592,433	492,171	-16.9	613,072	24.6
Fruit/Melons	tons	110,588	140,346	26.9	151,954	8.3
Tea	tons	513	500	-2.5	505	1.0
Hogs	head	525,656	254,410	-51.6	103,810	-59.2
Fowl	head	4,018,607	4,681,460	16.5	1,392,370	-70.3
Fish (Ponds)	tons	28,286	32,339	14.3	35,513	9.8
Shrimp/Crabs	tons	5,863	8,698	48.4	9,228	6.1
Aquaculture ponds	ha.	9000	8458	-6.0	7580	-10.4

Source: Nanjing City Jiangning District Statistical Bureau (2001: 47-76, Chapter 3; 2011: 43-60, Chapter 4; 2016: 48-67, Chapter 4).

Table 5 A Summary of Official Sown Area for Selected Crops for Jiangning District, Nanjing City, China: 2000, 2010 and 2015

YEAR	2000 (mu)	2010 (mu)	% change 2000 to 2010	2015 (mu)	% change 2010 to 2015
Total sown area (mu)	1,515,558	1,028,397	-32.14	933,300	-9.25
Grain sown area	659,232	464,765	-29.50	450,450	-3.08
Fall grains (wheat, barley)	72,908	86,353	18.44	109,350	26.63
Summer rice	504,654	329,942	-34.62	308,100	-6.62
Summer corn	16,263	11,474	-29.45	6,900	-39.86
Summer soybeans	35,571	17,995	-49.41	12,150	-32.48
Peanuts	10,320	6,594	-36.10	5,550	-15.83
Sesame	17,525	9,992	-42.98	8,400	-15.93
Rapeseed	405,960	173,652	-57.22	116,700	-32.80
Cotton	13,284	18,289	37.68	14,250	-22.08
Medicinal plants	10,109	0		300	
Vegetables	286,458	266,887	-6.83	256,500	-3.89
Fruit	49,916	58,669	17.54	65,550	11.73

YEAR	2000 (mu)	2010 (mu)	% change 2000 to 2010	2015 (mu)	% change 2010 to 2015
Green silage	24,019	18,450	-23.19	11,250	-39.02
Organic fertilizer	19,791	6,299	-68.17	2,550	-59.52

Source: Nanjing City Jiangning District Statistical Bureau (2001: 47-76, Chapter 3; 2011: 43-60, Chapter 4; 2016: 48-67, Chapter 4), and *Nanjing Statistical Yearbook* (2001; 2011; 2016).

We documented changes in farm labor and employment by sector, and changes in hukou status. From 2000 to the present, changes in gender composition of the farm workforce, and the reliance on migrant labor, seasonal and unregistered, were also identified trends (Table 6).

Table 6 Population and Rural Agricultural Labor Estimates for Jiangning District, Nanjing, PRC

YEAR	2000 (persons)	2010 (persons)	% change 2000 to 2010	2015 (persons)	% change 2010 to 2015
Total population	746,500	935,952	25.4	993,595	6.2
Population density/km^2	476	599.6	26.0	636,5	6.2
Jiangning population as % of Nanjing population	13.7	14.7	7.3	15.2	3.4
Rural (農村) population	586,550	509,184	-13.2	339,300	-33.4
Agricultural population in %	78.6	54.4	-30.8	34.1	-37.3
Agricultural labor	336,199	307,070	-8.7	292,716	-4.7

Sources:*Jiangning Statistical Yearbook* (2001: 40-41, Chapter 2); *Jiangning Tongji Nianjian* (2011: 13, 39, 57, Chapter 3); *Jiangning Tongji Nianjian* (2016: 17, Chapter 2); *Jiangsu Tongji Nianjian* (2016: 403).

The technical contribution of the research centered on Breidinger and Emerson's work on the misclassification problems associated with white PVC greenhouses, and the development of an object-oriented method to successfully incorporate adjustments so land covered by PVC greenhouses could be correctly classified as arable land.

In short, from a critical perspective, I believe we effectively completed many of the goals that are typically included in a traditional LU/LC study broadened by field work, interviews and the incorporation of the archived historical data that served as a check on analyses of remotely sensed variables (triangulation). In terms of the stated goals, established in our original grants, I guess, I would give our project a B, slightly above average. BUT, from an MA perspective, I think it should receive a grade of C, due largely to acts of omission. There were several other types of analyses we could have included using just the data we did collect. The next section summarizes these "roads not taken" that could have been addressed using only the data sets that we had in hand, but did not use to full potential.

What we did not do, BUT could have with the same data from an MA perspective

As noted above, while not complete for all years, we had sufficient data related to LU/LC change and shifts in forested and arable land at the jiedao scale to evaluate changes in carbon sequestration associated with changes in land types including public "green spaces" for most years from 2000 to 2016. Lin and Lin (2013) of National Chiayi University (Forestry and Natural Resources) offer a clear and useful blueprint for calculating these estimates. Another option would be the development of a tool similar to the USDA National Resource Conservation Service (USDA-NRCS, 2019) COMET-FARM (Comet-Farm 2019) program to assess carbon stored in arable land. COMET-FARM™ offers actual farm families a means for estimating carbon stored in soil: "producers enter information about their land and management using a secure online interface – including location, soil characteristics, land uses, tillage practices and nutrient use. …. The tool then estimates carbon sequestration and greenhouse gas emission reductions associated with conservation practices for cropland, pasture, and rangeland" (www.nrcs.usda.gov). The model is constantly being updated, and while so far used mostly for the lower 48 contiguous states of the US, with sufficient data, it could be adopted based on latitude and longitude for use in Jiangning. Using our existing arable land use change data, and data on area sown to specific crops, or crop categories, to calculate carbon storage for the period incorporated in our study would have significantly broadened the significance of our results and allowed us to enter into debates associated with carbon-sequestration and the mitigation of global warming associated with forest and farm land loss or gain. These results in turn could be used to discuss how to possibly monetize production strategies or conservation behaviors for farm families and local governments so as to promote carbon storage and arable land conservation as well.

Similarly, we could have analyzed the relative benefits of policies that promote return of land to forest areas, wood lots, "green spaces" and crop land in terms of carbon sequestration at a variety of temporal scales and made projections of carbon storage for the farm/forest sector of Jiangning district based on changing estimates of forest and agricultural land from 2000 to the present (Lin and Lin, 2013; Winsten *et al.*, 2011). Forest area in Jiangning actually increased from 2000 to 2015 from 11% to 19% (Table 1). We could also easily generate interpolated estimates via regression techniques for some future time period as well using the trend analysis module in SPSS.

For wealthy citizens of Nanjing, food safety scares have rapidly driven up demand for organic foods and enthusiasm for the "local foods" movement is also increasing (Veeck *et al.*, 2015). Many farms in Jiangning now specialize in organic tea, vegetables and fruits. A few of these farms or CO-OPs are managed by Taiwanese firms, and organic rice from Taiwan can be found in many up-scale supermarkets in Nanjing. These commodities have higher returns and the choice to produce them is driven by higher economic rents and the desire for higher wages (Aubry and Kebir, 2013). BUT, they also represent a potential off-set of greenhouse gases (GHG) as transport costs are lower for locally produced foods, and the use of manure, versus, inorganic fertilizers, lowers emissions as well. When manure is not used, due to labor constraints, it is often disposed of on undeveloped or vacant building lots, or along stream banks. We do not have expertise in GHG modelling, but there are many research reports that focus on the environmental benefits of local and organic food as these products increase in the supply chain, and we actually collected most of the data that is typically used in models for such analyses (Mundler and Laughrea, 2016). We could have broadened our research team with appropriate expertise, and again, using only the data we had already collected, provided a quantitative assessment on this topic.

What we didn't do, but could have with a new research design incorporating more MA goals.

The focus of the MA, or EA, movement is the promotion of holistic studies that document the interactions and feedback interactions between humans and their environments. In our study, in actuality, farm labor was treated only as a factor input which we linked to changes in production and arable land use change. The use of individual surveys of both farmers and consumers of local foods, organic foods could generate data that supports new models of arable land use based on new opportunities such as green tourism or agricultural tourism. We should have paid attention to the farm families as people who are part of the complex system.

Specifically, we did not assess the roles and lives of the migrant farmers who constitute the workforce. Since we were visiting farms already, we could have conducted micro-economic surveys for a sample of farmers' quality of life and economic security, and associated these data with changes in LU/LC. We could have learned about their views on bottlenecks in the farm to table supply chain, and how they felt incomes and environments could be improved.

Similarly, we could have linked our LU/LC data to a survey of all residents to investigate willingness to pay (WTP) for more greenspace, lower cost organic food, and local food initiatives that potentially could radically change the relationship of the migrant farmers and their families to the people around them by monetizing land conservation and assessing pubic support. Breidert *et al.* (2017) provide an excellent summary of a variety of potential WTP methods. Understanding WTP among the citizens of Jiangning and Nanjing could also influence local governments to more effectively protect and mitigate impacts of urbanization on agricultural and forested land.

There is a growing interest in real agricultural tourism throughout China, and Nanjing has become a leader in these efforts (not just restaurants in rural areas serving local foods) where consumers can meet farmers, experience a rural lifestyle and purchase organic farm fresh produce and semi-processed foods (fruits, vegetables, Longjing Tea, Yanshui Ya [salted duck], peaches, and others) (Scott *et al.*, 2018; Shen and Shen, 2017; Si and Scott, 2019)

All of these surveys or potentially qualitative research efforts would have allowed us to produce a much broader, but more detailed, picture of what is going on in the farm sector of Jiangning District, Nanjing and why. Such information is essential for policy formulation that assures adequate incomes, while protecting the environment.

Why did we “drop the ball” and why might researchers continue to do so in the future?

Why did we not make these extra efforts? From the freshman introductory lectures to my graduate classes, I am constantly stressing the holistic potential of Geography as a discipline, but yet, 30-plus years into my career, I did not fully incorporate the MA goals in the project, despite my admiration of the UN project. The easiest response is that in the course of developing the project, we developed a sort of “tunnel vision” antithetical to MA goals. This is undoubtedly true as there were several directions noted above that we could have incorporated in this research using pre-existing data.

Moving forward, researchers should think about exercising the true potential of geography by discussing our projects with a broader group of scholars, from different geographic specializations, but also from other disciplines. Yes, we are all very busy, but a few hours meeting with an informal working group of scholars at our colleges and universities would have helped educate us so as to understand the full potential of our data.

Expanding the research team is always an option. But there are potential problems there as well. After funding a pilot project in Inner Mongolia through NSF in 2005, Jay Emerson and I submitted a more comprehensive application for NSF and NASA in 2007. Our second NSF was rejected for a variety of reasons; it happens. Our NASA grant was also unfunded, but we were encouraged to resubmit the following year, which we did. A major concern for the initial (Year 1) reviewers was that we needed a climate modeler to link our LU/LC study to dust storms and other environmental damage beyond the location of our study. To make it more comprehensive, as in the MA vision. Emerson and I had only very modest salary inclusions in the grant, but the scholar that came recommended by one of the reviewers, who seemed ideal, required months of salary. The long and short of this was that the reviewers of the second year application liked the grant, but did not fund it as they thought it too expensive vis-à-vis the deliverables of the research. Building the research teams required for genuine MA research, with a high level of expertise, may be more expensive and moves the researcher into the most competitive category of high-award but highly competitive grants.

There are also, however, some other structural conditions that confront most researchers in geography and cognate fields, and may limit synthetic MA research. Firstly, there is the grant review process. Funding for geographic research is limited and we tend to develop grant applications that “mirror” successful funded projects from the same funding sources, or at the least, I do. It seems to me, admittedly a sample of one, that reviewers and funding agency personnel prefer focused projects, with a strong emphasis on unique contributions. Most grants, at least from North American funding sources, limit the length of applications by the number of pages or words. NSF allows 10 single-spaced pages. NASA is 10 pages. National Geographic is 10 pages. Creating a successful comprehensive EA-inspired project application that incorporates effective coverage of existing literatures for three or four different research areas along the lines of MA-inspired research in ten pages is a challenge. What goes for grant applications, is often, but not always, similar for publications. Again, there are word limits. Often, article reviewers focus on the portion of the work related to their specific areas of expertise, so reviews of EA research by three or four reviewers can require very different sets of changes. Editors must make the difficult call, i.e. the research is interesting, but reviewers have too many issues with too many parts of the project. If research is focused on a single accepted sub-discipline or topic, the reviews are more focused, and funding and publication more successfully achieved.

On-line journals (open access or not) have the potential to mitigate this problem by allowing longer, more comprehensive, publications with data appendices, but many journals that have moved on-line really still follow the 5,000 to 10,000 words limit required for the "old" print submissions. Still, I think there is a good trend to anticipate here. Rather than recreate the print publication on line, it might be that the print version would be a summary that refers readers back to the on-line version. Many journals in the chemical and biological sciences already do this, especially for the provision of data or analytical procedures.

Conclusions: Comprehensive Research Design and Anticipatory Data Collection.

Conducting truly comprehensive human-environmental research is the goal, the ideal, not just of the MA vision, but of geography in many cases as well. There are always compromises related to time, expertise, and funding. No project is perfect. There is great and increasing pressure to publish in a timely manner. While quality of publications should be the major factor, numbers matter as well; just as they matter in all other disciplines in 2020. The time required for more ambitious truly holistic projects may not be available given rising teaching loads and the "publish or perish" environment. But those of us working on environmental goals should try to produce products that directly speak to the broader environmental audience that was so inspired by the EA vision.

Geography has a role to play, we can make a difference, but this means we must plan our research more carefully, identify systems and sub-systems in advance, and work to more effectively combine human and environmental elements and their interactions in our research whenever appropriate and possible. To accomplish this, we should seek membership in multi-disciplinary teams, seek cross-disciplinary funding, and above all, design our projects—from the outset—with an awareness how to collect as many variables as possible using as many methods as appropriate so as to successfully achieve holistic human-environment research. We must get out of our academic institutions and form public-private advisory groups where funding for longer term more comprehensive projects can be developed with less dependence on our traditional funding agencies.

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投稿日期：110 年 05 月 13 日
修正日期：110 年 08 月 24 日
接受日期：110 年 11 月 03 日