

<b>Title of Grant / Cooperative Agreement:</b>	Increased accessibility, landscape changes, rural transformations, and urbanization: Impacts of the east-west economic corridor from Da Nang, Vietnam, to Khon Kaen, Thailand
<b>Type of Report:</b>	Summary of Research
<b>Name of Principal Investigator:</b>	Stephen J. Leisz
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<b>Name and Address of recipient's institution:</b>	Colorado State University Fort Collins, CO 80523
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**Reference 14 CFR § 1260.28 Patent Rights** (*abbreviated below*)

The Recipient shall include a list of any Subject Inventions required to be disclosed during the preceding year in the performance report, technical report, or renewal proposal. A complete list (or a negative statement) for the entire award period shall be included in the summary of research.

Subject inventions include any new process, machine, manufacture, or composition of matter, including software, and improvements to, or new applications of, existing processes, machines, manufactures, and compositions of matter, including software.

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If yes a complete listing should be provided here: Details can be provided in the body of the Summary of Research report.		

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A Final Inventory Report of Federally Owned Property, including equipment where title was taken by the Government, will be submitted by the Recipient no later than 60 days after the expiration date of the grant. Negative responses for Final Inventory Reports are required.

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***Attach the Summary of Research text behind this cover sheet.***

**Reference 14 CFR § 1260.22 Technical publications and reports (December 2003)**

Reports shall be in the English language, informal in nature, and ordinarily not exceed three pages (not counting bibliographies, abstracts, and lists of other media).

A Summary of Research (or Educational Activity Report in the case of Education Grants) is due within 90 days after the expiration date of the grant, regardless of whether or not support is continued under another grant. This report shall be a comprehensive summary of significant accomplishments during the duration of the grant.

## Summary of Research:

This report summarizes the scientific findings from the “Increased accessibility, landscape changes, rural transformations, and urbanization: Impacts of the east-west economic corridor (EWEC) from Da Nang, Vietnam, to Khon Kaen, Thailand” project which had an inception date of January 1, 2013 and was finished on April 1, 2017. Grant number NNX13AC51G.

The goal of the project was to identify the role that the EWEC plays in the changing landscape of central Vietnam, southern Laos, and northeastern Thailand and its influence on the region’s land-cover/use changes and urbanization process. In order to investigate this goal, the following questions helped to focus the research:

- Has land-cover/land-use change (LCLUC) occurred within the vicinity of the road and within the corridor since upgrades were completed? How?
- Has urbanization taken place along the road? If so, what is the nature of the urbanization? (Is it continuous urbanization (e.g. infilling, edge expansion, or spontaneous growth) or is it the “rural urbanization” noted by Riggs (2001)? Where does it fit on the ‘continuum’ proposed by Seto et al. (2012)?)
- Are urban-rural teleconnections (telecouplings) evident in the EWEC (Seto et al. 2012)?
- If so, are urban-rural teleconnections (telecouplings) cross-border or confined within each country?
- Are there discernible differences between urban-rural transformations between the three countries? What are the differences? What are the drivers?
- Do past development paths followed by different countries impact on LCLUC along the road?
- How do government policies play a role in LCLUC and urbanization within the EWEC?
- How do these policies, and their impacts, differ between the countries?

In order to address these questions this report will address three major findings: (1) LCLUC within the corridor since completion of the upgrades; (2) Teleconnections/telecouplings within the EWEC; (3) Differences in land changes within the EWEC between the three countries.

### 1. LCULC within the corridor since completion of the upgrades

In order to investigate LCLUC within the corridor three different analyses were carried out, (a) hyper-temporal analysis of 212 MODIS EVI scenes from 2002 to 2014, (b) analysis of Landsat TM and ETM data from the decades 1990 – 1999, 2000 – 2010, 2010 – 2014, and (c) for Thailand, analysis of land-use map data for 2001, 2006, 2007, 2014 and 2015. A brief overview of the results follows.

#### (a) Hyper-temporal analysis

Two stacks of 212 MODIS composite EVI images (250 m pixel resolution) were analyzed, one for the eastern and one for the western parts of the corridor (horizontally and vertically identified as h27v07 and h28v07 respectively). ERDAS Imagine software was used to analyze each stack. For each stack an unsupervised ISODATA classification was done. Each stack was divided into 250 classes, with minimum class size of 0.01% of the total pixels. The classification was set to end if a convergence threshold of 0.9995 was reached or 150 iterations finished. Once classes were divided they were analyzed to identify changes. The harmonic terms of the phenological characteristics of each classes signature over the 12 years was analyzed for changes (Park 2010).

If there was a change in the characteristics, the class was flagged for investigation using higher resolution data. For Vietnam and Laos the only changes identified at this scale (pixel resolution) were changes near urban areas (Figure 1) and changes due to reservoir construction.

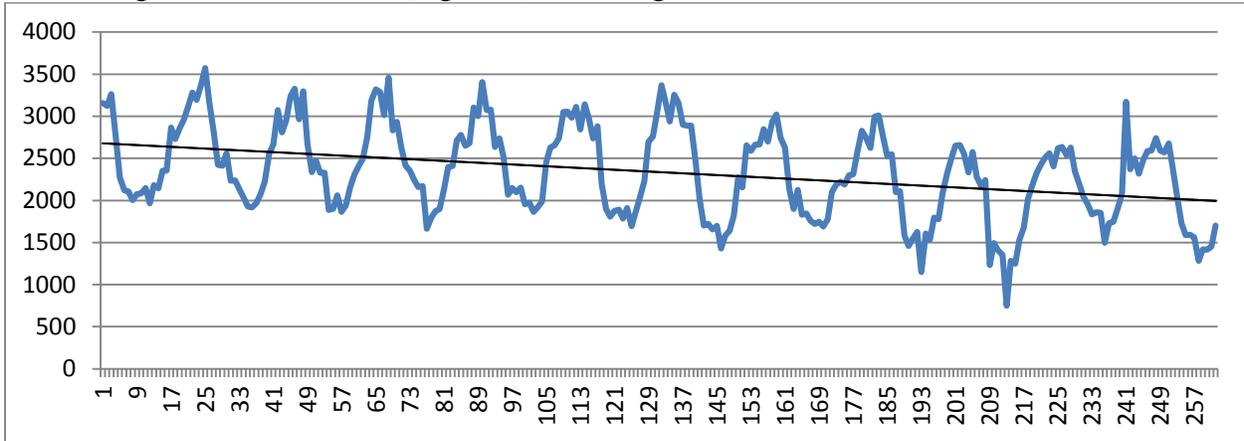


Figure 1. Change over time from single crop per year agriculture areas to built-up areas.

Rural areas in Vietnam and Laos were dominated by classes showing consistent seasonal agriculture or tree cover over the time period, with little observable LCLUC at the scale of analysis possible using MODIS data.

The only rural areas that indicated LCLUC leading to more tree cover was found in northeastern Thailand. In this area of the EWEC there were two classes of pixels that show a change in their signature indicating more vegetation per pixel (Figure 4). An investigation of these areas using higher resolution imagery and ground visits uncovered that these changes are due to increased tree cover (tree crops such as eucalyptus and rubber) per pixel area.

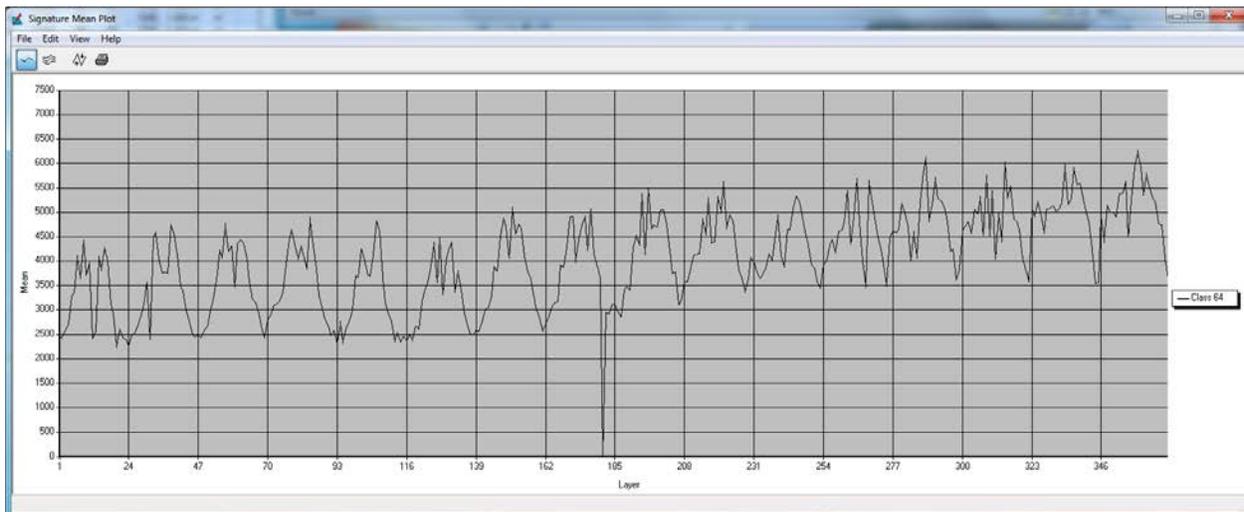


Figure 4. One of the two class signatures indicating increasing vegetation per pixel.

(b) Landsat TM and ETM+

An analysis of Landsat TM and ETM+ data was done for urban areas within the EWEC as well as rural case study areas. The findings for the analysis of urban area change were presented to local policy makers in Vietnam and Laos as well as within presentations and at The 2<sup>nd</sup>

International UGEC Conference in Taipei, Taiwan in 2014 and at the American Association of Geographers meeting in 2016. Results showed expansion of cities in the corridor and newly urbanizing rural village areas and border areas. Rural areas changes were investigated to look at changes in agricultural landscape patterns. These analyses were done for the upland areas of Quang Tri, Vietnam, and Savannakhet Laos. Results of this analysis are reported in Leisz et al. (2016).

(c) Land-use map data analysis

Map analysis of Thai land-use map data is on-going. Initial results are further confirming the MODIS hyper-temporal analysis results that there has been an increase in tree-cover in the EWEC between Mukdahan and Khon Kaen in Thailand. A paper is in preparation.

2. Teleconnections/telecouplings within the EWEC

Telecouplings were found to be significant drivers of change within the corridor. Leisz et al. (2016) document the different telecouplings between urban areas and areas outside the corridor, and between rural and urban areas and rural areas inside the corridor and effects on urban and rural development in the corridor and LCLUC. Urban areas, especially their associated industrial zones (IZ) are found to be directly affected by outside investments, both from other locations in Vietnam and from outside the country. Rural areas are affected, indirectly, by the investments in urban areas and also directly by investment from outside the EWEC in rural industrial complexes at the borders and near the borders between Laos and Vietnam, and Laos and Thailand. These developments influence rural people to change the agricultural crops that they grow and also the placement of their fields. These land-use changes have in turn influenced rural land-cover. In rural villages in Vietnam agricultural fields were moved closer to the improved roads (primary and secondary roads) and tree crops were planted in fields further from the roads or more distant swidden fields are left fallow for longer periods of time. In Laos there is less influence in field placement, but crop mixes changed as more cassava and bananas were planted. In Thailand, there are more shops and small-industries locating near the roads and more off-farm employment opportunities that are providing employment opportunities. These are indirectly affecting land-use choices and ultimately land-cover as tree crops are favored over seasonal crops in some places (Shirai et al. [in review]).

3. Differences in land changes within the EWEC between the three countries.

All three of the countries have experienced land changes in the EWEC since transportation routes were upgraded and EWEC border agreements implemented. However, the intensity of changes has varied due to the historical changes that had already taken place as well as varying government policies. In Vietnam government investments and policies have influenced development of border IZs, as well as IZ placements near urban areas; land tenure policies have also had an effect on village level land management which directly influences the land-use choices of farmers. Laos land tenure and industrial policies have influenced IZ development (more around Savannakhet, none at border with Vietnam) and also farmer land-use choices, but rural areas have not seen the investment in tree crops that have been made in Vietnam. Policy agreements were reported to have impacted on the expansion of logistics services companies near Mukdahan and in some cross-border IZ investments in Laos from Thailand.

## **Addendum: Bibliography, Conferences, and Abstracts**

### Papers (Published)

Shirai, Yuko, Jefferson Fox, Stephen Leisz, Hayao Fukui, A. Terry Rambo (2017) The Influence of Local Non-Farm Employment on Rural Household Structure in Northeast Thailand. *Journal of Rural Studies* 54:52-59.

Leisz, Stephen, Eric Rounds, Ngo The An, Nguyen Thi Bich Yen, Trn Nguyen Bang, Souvanthone Douangphachanh, Bounheuang Ninchaleune (2016) Urban-rural telecouplings in the East-West Economic Corridor within borders and across. *Remote Sensing* 8 (12), 1012; doi:10.3390/rs8121012.

Leisz, Stephen J., and Ngo The An (2015) TÁC ĐỘNG CỦA HÀNH LANG KINH TẾ ĐÔNG TÂY ĐẾN BIẾN ĐỘNG SỬ DỤNG ĐẤT VÀ CHE PHỦ ĐẤT (Influence of the East-West Economic Corridor on Land-Use and Land-Cover) (2015) Proceedings of the Vietnam National Conference on Environment, Ministry of Natural Resources and Environment. MONRE, Hanoi, Vietnam.

### Papers (Submitted and in preparation)

Shirai, Yuko, Stephen Leisz, Jefferson Fox, A. Terry Rambo (in review) Does Rural Industrialization Reduce Out-Migration? Commuting Distance, Levels of Local Non-Farm Employment and Out-Migration in Rural Villages in Northeast Thailand. *Applied Geography*.

Shirai, Yuko, Leisz, J. Stephen, Fox, Jefferson and Rambo, A. Terry (in review) Rural Household Characteristics and Agricultural Activities in Relation to Local Non-Farm Employment: A Comparative Study of Two Wet Rice-Growing Villages in Northeast Thailand. *The Khon Kaen Agriculture Journal*, Khon Kaen University.

Leisz, Stephen J., Eric Rounds (in preparation). Hypertemporal analysis of land-cover changes in the East-West Economic Corridor from Vietnam to Khon, Kaen, Thailand (in preparation). *Remote Sensing of Environment* (target journal).

Rounds, Eric, Stephen J. Leisz (in preparation) Connectivity and Distant Drivers of Land Change: A Case Study of Land Use, Land Cover, and Livelihood Changes in Quang Tri, Vietnam (in preparation). *Environmental Management* (target journal).

Shirai, Yuko, Stephen Leisz, Jefferson Fox, A. Terry Rambo (in preparation) Factory Workers and Farmers: Agricultural Transformations? The Influence of the Availability of Local Non-Farm Employment on Agricultural Activities in Rural Villages in Northeast Thailand. *Land Use Policy* (target journal).

### Conference Presentations and Invited talks

- 3 March 2017 Stephen Leisz (invited speaker). “Telecouplings in the East-West Economic Corridor.” NRM Field of Study Seminar Series 2017, Asian Institute of Technology, Bangkok, Thailand.
- 28 February 2017 Stephen Leisz. “Land Changes in Savannakhet, Laos, and Mukdahan, Kalasin and Khon Kaen in Northeast Thailand. Seminar for Review of Urban and Rural Changes in the East-West Economic Corridor from Da Nang, Vietnam, to Khon Kaen, Thailand, Over the Past Decade, JICA Thailand Office, Bangkok, Thailand.
- 29 March – 2 April 2016 Stephen Leisz. “Urban-rural teleconnections along the East-West Economic Corridor within borders and across borders,” in Forest, agricultural, and urban transitions in Mainland Southeast Asia: Synthesizing knowledge and developing theory. AAG Annual Meeting, San Francisco, California.
- 12 – 13 December 2015 Stephen Leisz. “Urban-rural teleconnections in Vietnam, Laos, and Northeast Thailand: are urban/rural boundaries still evident?” Southeast Asian Studies in Asia Conference, Kyoto, Japan.
- 29 - 30 September 2015 Stephen J. Leisz and Ngo The An. TÁC ĐỘNG CỦA HÀNH LANG KINH TẾ ĐÔNG TÂY ĐẾN BIẾN ĐỘNG SỬ DỤNG ĐẤT VÀ CHE PHỦ ĐẤT (Influence of the East-West Economic Corridor on Land-Use and Land-Cover), Vietnam National Conference on Environment, Ministry of Natural Resources and Environment, Hanoi, Vietnam.
- 16 March 2015 Stephen Leisz (invited speaker). “Teleconnections and rural and urban land-cover changes in Central Vietnam, Southern Laos, and Northeast Thailand.” GSE Seminar Series Spring 2015, South Dakota State University, Brookings, South Dakota.
- 6 – 8 November 2014 Stephen Leisz. “Road development, rural and urban land-cover/use changes and urban expansion.” Urban Land Teleconnections: From Concept to Implementation. The 2<sup>nd</sup> International UGEC Conference, Taipei, Taiwan.

### Master’s Thesis

Eric Rounds (2016) *Connectivity and Distant Drivers of Land Change: A Case Study of Land Use, Land Cover, and Livelihood Changes in Quang Tri, Vietnam*. (Advisor: Associate Professor Stephen J. Leisz). Department of Anthropology, Colorado State University, Fort Collins, Colorado, USA.

## **Addendum: Abstracts**

Abstract: Shirai, Yuko, Jefferson Fox, Stephen Leisz, Hayao Fukui, A. Terry Rambo (2017) The Influence of Local Non-Farm Employment on Rural Household Structure in Northeast Thailand. *Journal of Rural Studies* 54:52-59.

This paper examines how the structure of rural households in Northeast Thailand is influenced by the availability of local non-farm employment opportunities. It compares the frequency of different types of households (i.e., nuclear, extended, skipped generation, and truncated households) in two villages that were similar in most respects but differed in the shares of households with members having local non-farm employment. Almost three-quarters of all households in the village with a large share of households having members with local non-farm employment were of the extended and nuclear types. In the village with a small share of households having members with such employment, half of all households were of the skipped generation and truncated types. The extent of out-migration of young adult villagers seeking jobs in large cities also varied according to the availability of local non-farm employment. The village where many households have members with local non-farm employment had a smaller number of out-migrants. This contributes to its having more extended and nuclear households and fewer skipped generation and truncated households than the village with a greater number of out-migrants. These findings suggest that, in an area undergoing rapid economic development and modernization, rural household structure is strongly influenced by specific local economic conditions, in this case the availability of non-farm employment, rather than resulting from a universal trend toward the dominance of nuclear households as posited by convergence theory.

Abstract: Leisz, Stephen, Eric Rounds, Ngo The An, Nguyen Thi Bich Yen, Trn Nguyen Bang, Souvanthone Douangphachanh, Bounheuang Ninchaleune (2016) Urban-rural telecouplings in the East-West Economic Corridor within borders and across. *Remote Sensing* 8 (12), 1012; doi:10.3390/rs8121012.

In recent years, the concepts of teleconnections and telecoupling have been introduced into land-use and land-cover change literature as frameworks that seek to explain connections between areas that are not in close physical proximity to each other. The conceptual frameworks of teleconnections and telecoupling seek to explicitly link land changes in one place, or in a number of places, to distant, usually non-physically connected locations. These conceptual frameworks are offered as new ways of understanding land changes; rather than viewing land-use and land-cover change through discrete land classifications that have been based on the idea of land-use as seen through rural–urban dichotomies, path dependencies and sequential land transitions, and place-based relationships. Focusing on the land-use and land-cover changes taking place along the East–West Economic Corridor that runs from Dong Ha City in Quang Tri, Vietnam, through Sepon District, Savannakhet, Lao PDR, into Thailand this paper makes use of data gathered from fieldwork and remote sensing analysis to examine telecouplings between sending, receiving and spill-over systems on both sides of the Vietnam-Lao PDR border. Findings are that the telecouplings are driving changes in rural village and urban systems on both sides of the border, and are enabled by a policy environment that has sought to facilitate the cross-border transportation of goods within the region.

Abstract: Shirai, Yuko, Stephen Leisz, Jefferson Fox, A. Terry Rambo (in review) Does Rural Industrialization Reduce Out-Migration? Commuting Distance, Levels of Local Non-Farm Employment and Out-Migration in Rural Villages in Northeast Thailand. *Applied Geography*.

This study examines the impact of local non-farm employment opportunities and out-migration on agricultural practices and land-use in rural villages in Northeast Thailand. A total of 88 randomly selected villages were studied in two sites in the Northeast. Development of local industries in these areas has impacted agriculture and land-use and out-migration: villages where few residents engage in local non-farm work have a greater variety of agricultural activities than villages where there are more people engage in local non-farm work. In villages where there are fewer residents with regular wage non-farm jobs, there are larger numbers of out-migrants. In these villages households engage in a larger variety of agricultural activities, more agricultural land belongs to the local residents, and land is used mainly for growing rice to provide security against unemployment. Villages that have more regular and casual hire wage workers have more households that have no land for agriculture compared to villages with fewer local non-farm workers.

Abstract: Shirai, Yuko, Leisz, J. Stephen, Fox, Jefferson and Rambo, A. Terry (in review) Rural Household Characteristics and Agricultural Activities in Relation to Local Non-Farm Employment: A Comparative Study of Two Wet Rice-Growing Villages in Northeast Thailand. *The Khon Kaen Agriculture Journal*, Khon Kaen University.

This study examines the impact of local non-farm employment on agriculture in rural villages in Khon Kaen Province in Northeast Thailand. Two villages having similar populations, land forms and topography, and agricultural systems, but differing in the number of workers employed in local non-farm regular wage jobs were selected. The availability of local non-farm regular wage job opportunities was found to exert a strong influence on out-migration, household structure, and agricultural activities in these villages. Households having members with local non-farm jobs have few out-migrants and are more likely to be extended and nuclear type households. These types of households are able to expand their agricultural activities by using family labor and investing in farm machinery. They are also able to transplant rice seedlings, which is more labor-intensive than broadcast seeding which is often used by households that lack sufficient labor. In contrast, there are many out-migrants from households that have limited opportunities to work in local regular wage non-farm jobs. These households are more likely to be of the skipped generation and truncated types. Because their labor supply is small and they often lack sufficient cash income, they resort to broadcast rice seeding in order to save labor and investment cost. Government promotion of rural industrialization may be an effective strategy to reduce rates of out-migration and develop more stable and prosperous agricultural communities in Northeast Thailand.

Abstract: Rounds, Eric. *Connectivity and Distant Drivers of Land Change: A case study of land use, land cover, and livelihood changes in Quang Tri, Vietnam*. (Master's Thesis)

The urban lowland areas of Vietnam have been at the forefront of economic liberalization over the last 30 years, while the more remote mountainous areas of the country have lagged behind.

Upland areas in the Northern and Central portions of Vietnam in particular remain largely impoverished and disconnected from broader national and regional markets. To address this economic inequality in the uplands, recent economic development efforts such as the East-West Economic Corridor (EWEC) have aimed at expanding road infrastructure to remote areas in Central Vietnam. This paper examines the impact of road expansion in the EWEC on a single village in Quang Tri, Vietnam. It draws from social data gathered during fieldwork and a historical land cover analysis to answer how land use, land cover, and livelihoods have changed in recent decades. Moreover, the paper discusses the drivers of these changes, both distal and proximate, and how these drivers were influenced by improved road access. Findings show that the improved road connectivity provided by new roads has facilitated the transmission of distant market-related drivers into the study area, and that these drives have underpinned significant changes in land use, land cover, and livelihoods.