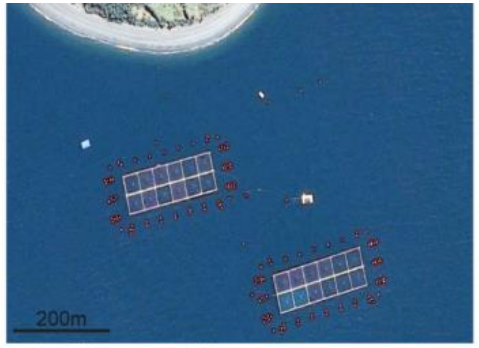
Sentinel-1 to estimate Aquaculture Production: Opportunities and Challenges

Copernicus for Fisheries and Aquaculture Workshop, Brussels, 2 October 2018

Marco Ottinger, J. Huth, P. Leinenkugel, C. Kuenzer

Department of Land Surface Dynamics
German Remote Sensing Data Center (DFD)
Earth Observation Center (EOC)
German Aerospace Center (DLR)

Introduction: Land-based Aquaculture



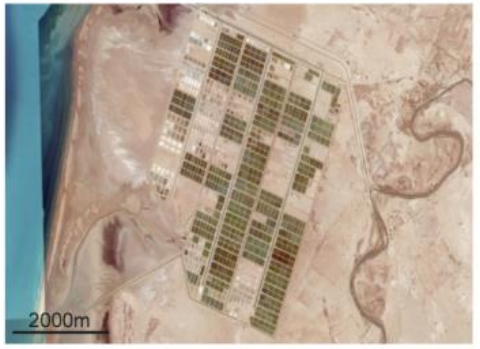
Marine offshore cages, Chile

Fish farm, Uganda

Shrimp farm, Mexico

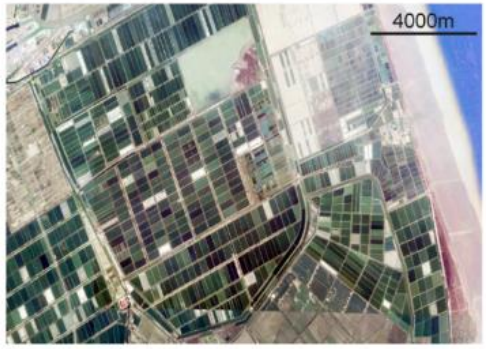
Shrimp farm, Malaysia

Marine cage aquaculture, China



Shrimp farm, Iran

Shrimp ponds, Ecuador



Fish farms, China

Raceway system, Peru

Aquaculture ponds, Vietnam

Aquaculture ponds, Thailand

Aquaculture ponds, Indonesia

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Review

Aquaculture: Relevance, distribution, impacts and spatial assessments – A review

Marco Ottinger [a, *], Kersten Clauss [a], Claudia Kuenzer [b]
[a] Department of Remote Sensing, Institute of Geography and Geology, University of Wuerzburg, 97074 Wuerzburg, Germany
[b] Earth Observation Center, EOC, German Aerospace Center, DLR, 82234 Wessling, Germany

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ABSTRACT
Aquaculture is the fastest-growing animal food production sector worldwide and is becoming the main source of aquatic animal food in human consumption. Depletion of wild fishery stocks, rising global populations, continuing demand for food fish, and international trade has driven aquaculture's tremendous expansion during the last decades – in terms of production volume and value. Farmed aquatic products are among the most widely traded commodities in the world food economy. Aquaculture has mainly been developed in valuable fertile coastal environments and caused large-scale land use changes, destruction and loss of coastal wetlands and pollution of waters and soils. This article presents an overview of the relevance, current status and distribution of aquaculture in global and environmental impacts. Quantitative assessment of the spatial extent, for a sustainable management of our

1. Introduction

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et al., 2012; OECD/FAO
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http://dx.doi.org/10.101
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remote sensing
MDPI
Article

Large-Scale Assessment of Coastal Aquaculture Ponds with Sentinel-1 Time Series Data

Marco Ottinger [1,*], Kersten Clauss [1] and Claudia Kuenzer [2]
1 Department of Remote Sensing, Institute of Geography and Geology, University of Wuerzburg, D-97074 Wuerzburg, Germany; kersten.clauss@dlr.de
2 German Aerospace Center (DLR), German Remote Sensing Data Center (DFD), D-82234 Wessling, Germany; claudia.kuenzer@dlr.de
* Correspondence: marco.ottinger@dlr.de; Tel.: +49-8153-28-1510

Academic Editors: Deepak R. Mishra, Xiaofeng Li and Prasad S. Thenkabail
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Abstract: We present an earth observation based approach to detect aquaculture ponds in coastal areas with dense time series of high spatial resolution Sentinel-1 SAR data. Aquaculture is one of the fastest-growing animal food production sectors worldwide, contributes more than half of the total volume of aquatic foods in human consumption, and offers a great potential for global food security. The key advantages of SAR instruments for aquaculture mapping are their all-weather, day and night imaging capa
particularly to cloud-prone coastal regions. The different backscatter responses o
surface) and aquaculture's distinct rectangular str
bodies. We analyzed th
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Keywords: aquacul
coastal zone; river d

1. Introduction

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MDPI
Article

Opportunities and Challenges for the Estimation of Aquaculture Production Based on Earth Observation Data

Marco Ottinger [1,2,*], Kersten Clauss [1] and Claudia Kuenzer [2]
1 Department of Remote Sensing, Institute of Geography and Geology, University of Wuerzburg, 97074 Wuerzburg, Germany; kersten.clauss@dlr.de
2 German Remote Sensing Data Center (DFD), Earth Observation Center (EOC), German Aerospace Center (DLR), 82234 Wessling, Germany; claudia.kuenzer@dlr.de
* Correspondence: marco.ottinger@dlr.de; Tel.: +49-8153-28-1510

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check for updates

Abstract: Aquaculture makes a crucial contribution to global food security and protein intake and is a basis for many livelihoods. Every second fish consumed today is produced in aquaculture systems, mainly in land-based water ponds situated along the coastal areas. Satellite remote sensing enables high-resolution mapping of pond aquaculture, facilitating inventory analyses to support sustainable development of the planet's valuable coastal ecosystems. Free, full and open data from the Copernicus earth observation missions opens up new potential for the detection and monitoring of aquaculture from space. High-resolution time series data acquired by active microwave instruments aboard the Sentinel-1 satellites and fully automated, object-based image analysis allow the identification of aquaculture ponds. In view of the diversity and complexity in the production of aquaculture products, yield and production varies greatly among species. Although national statistics on aquaculture production exist, there is a large gap of pond-specific aquaculture production quantities. In this regard, earth observation-based mapping and monitoring of pond aquaculture can be used to estimate production and has great potential for global production projections. For the deltas of the Mekong River, Red River, Pearl River, and Yellow River, as one of the world's most significant aquaculture production regions, we detected aquaculture ponds from high spatial resolution Sentinel-1 Synthetic Aperture Radar (SAR) data. We collected aquaculture production and yield statistics at national, regional and local levels to link earth observation-based findings to the size, number and distribution of aquaculture ponds with production estimation. With the SAR derived mapping product, it is possible for the first time to assess aquaculture on single pond level at a regional scale and use that information for spatial analyses and production estimation.

Keywords: aquaculture; sentinel-1; coastal zone; earth observation; food security

MARCO OTTINGER, VO QUOC TUAN, CLAUDIA KÜNZER

Aquakultur im Mekong-Delta: Segen oder Fluch?

Das Mekong-Delta in Vietnam ist eine intensiv landwirtschaftlich geprägte Region, in der 50 % der Gesamtfläche für Reisanbau sowie 18 % für Aquakultur genutzt werden. Die Zucht von Fisch und Shrimps hat sich seit Mitte der 1990er Jahre von 0,26 auf 2,22 Mio. t erhöht. Großräumige Landnutzungsveränderungen sowie Verlust und Degradierung wertvoller Feuchtgebiete sind die Folge. Aquakultur verursacht erhebliche Umweltverschmutzung mit weitreichenden sozialen und ökonomischen Folgen. Der Einsatz von Erdbeobachtungsinstrumenten ermöglicht eine großflächige Erfassung und Quantifizierung von Aquakultur und der im Zusammenhang stehenden Umweltveränderungen.

Flussdeltas gehören zu den fruchtbarsten und produktivsten (*Kuenzer* und *Renaud* 2012) sowie am dichtesten besiedelten Gebieten der Erde (*Ottinger* et al. 2013). Das Delta des Mekong ist mit rund 40 500 km² Gesamtfläche etwa so groß wie die Schweiz und beheimatet ca. 17,5 Mio. Einwohner (GSO 2014). Gelegen im tropischen, monsunbeeinflussten Klima an der Südspitze Vietnams (vgl. *Abb. 1*) ist es durch seine exponierte Lage zum Meer und eine sehr flache Topographie gekennzeichnet. Der Mekong ist Lebensraum einer Vielzahl an Fischarten und ist aufgrund der jährlichen Überflutungsdynamik und des Eintrags großer Mengen nährstoffreicher Sedimente von hohem ökologischen Wert für die Fertilität dieser Region (*Kuenzer* et al. 2013, *Mader* et al. 2012). Dank günstiger klimatischer Bedingungen, fruchtbarer Böden und großer Frischwasserressourcen (*Renaud* und *Kuenzer* 2012) entwickelte sich das Mekong-Delta zu Vietnams Hauptregion für Reisanbau und Fischzucht. Dort finden 56 % der nationalen Reisproduktion sowie 70 % der Aquakultur-Produktion statt (GSO 2014).

Im globalen Maßstab ist Aquakultur in Küstenregionen von hoher Brisanz. Weltweit stieg die Produktion von Aquakultur von 1982 bis 2012 von 5,56 auf 66,6 Mio. t und ist mit einer jährlichen Zuwachsrate von 8,6 % der am schnellsten wachsende Sektor in der globalen Nahrungsmittelwirtschaft (*Allison* 2011, UN 2011). Bereits heute stammt fast die Hälfte aller Speisefische aus Aquakulturen, wovon nahezu 90 % in Asien produziert werden. Vietnam ist mit 3,09 Mio. t der weltweit drittgrößte Aquakultur-Produzent (FAO 2014), und Fischerzeugnisse tragen 10 % zum Bruttoinlandsprodukts bei (*Allison* 2011).

Süßwasserfische sind in Vietnam wegen ihres weißen Fleisches sehr beliebte Speisefische und Haupt-

Entwicklung der Aquakultur im Mekong-Delta

Die wachsende Bevölkerung und ein verändertes globales Konsumverhalten sind wichtige Gründe für die gestiegene Nachfrage für Fisch, Garnelen und anderen aquatischen Organismen im In- und Ausland. Seit den 1960er Jahren hat sich der jährliche durchschnittliche Fischkonsum pro Kopf von 10 kg auf 19 kg beinahe verdoppelt (FAO 2014). Im Mekong-Delta haben die unter dem Begriff Doi Moi (Vietnamesisch für ‚Erneuerung') bekannten, im Jahr 1986 initiierten marktwirtschaftlichen Reformen den Bauern mehr Entscheidungsfreiheit und Flexibilität hinsichtlich der Verwaltung ihrer landwirtschaftlichen Flächen überlassen und ein selbstständiges Wirtschaften ihrer Felder ermöglicht (*Garschagen* et al. 2012).

Da mit der Zucht von Fisch und Fischprodukten ein höheres Einkommen als mit traditioneller Landwirtschaft erzeugt werden kann, ist Aquakultur gerade für Kleinbauern ein lohnendes Geschäft. Dies motivierte mehr und mehr Bauern zu einem Wechsel vom Reisanbau zur Aquakultur. Diese hat sich in den letzten zehn Jahren zu einer stark exportorientierten Industrie entwickelt. Vor allem hochwertige Fisch- und Shrimp-Arten werden in großen Mengen für die Märkte in der EU, den USA und Japan produziert (*Genschick* 2011).

Allerdings führt die Aquakultur im Mekong-Delta wegen der Einleitung von Abwässern und des Einsatzes von Düngemitteln, Antibiotika und Pestiziden zu Wasserverschmutzung und einer erheblichen Belastung der Umwelt (vgl. *Abb. 2*). Schadstoffeintrag und

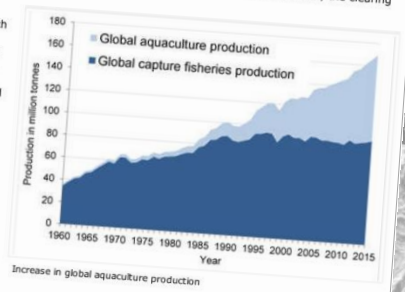
DLR Earth Observation Center

Strong Growth in Aquaculture Threatens Ecosystems

26 January 2018

Aquaculture is the fastest growing sector of the food industry worldwide and meanwhile supplies almost half of all fish that people consume. With methodology developed at EOC this growth can be detected over a wide area. On the Asia coasts the expansion of aquaculture leads to ecosystem destruction, the clearing of mangrove forests, and water pollution.

Aquaculture is the controlled breeding of aquatic organisms such as fish, shrimp and mussels. In contrast to wild-capture fishery, it usually takes place in water tanks onshore. Aquaculture today accounts for 45 percent of the total production of aquatic products. With an average annual growth rate of 6.7 percent, global aquaculture production has increased five-fold from 13 million tons in 1990 to 76 million tons in 2015. A growing world population and changed consumer behaviour have led to an increased demand for fish, mussels and shellfish, which provide essential fatty acids and proteins. Fish consumption has doubled on average since the 1960s and today amounts to 19 kg



Increase in global aquaculture production

almost 90% of global
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These include the
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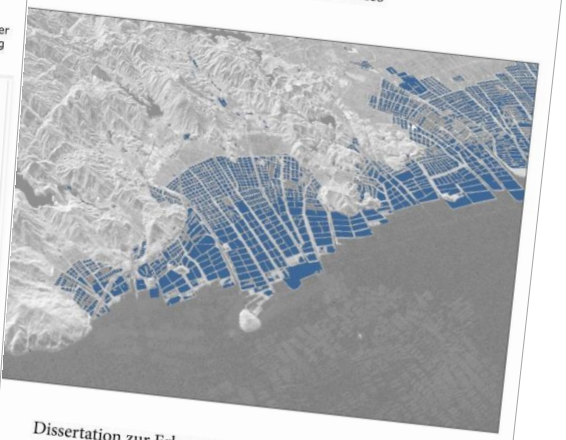
Aquacultu

Earth Observation for the Assessment of Aquaculture in Coastal Regions

Deriving Aquaculture Areas and Estimating Production based on High Resolution SAR Time Series

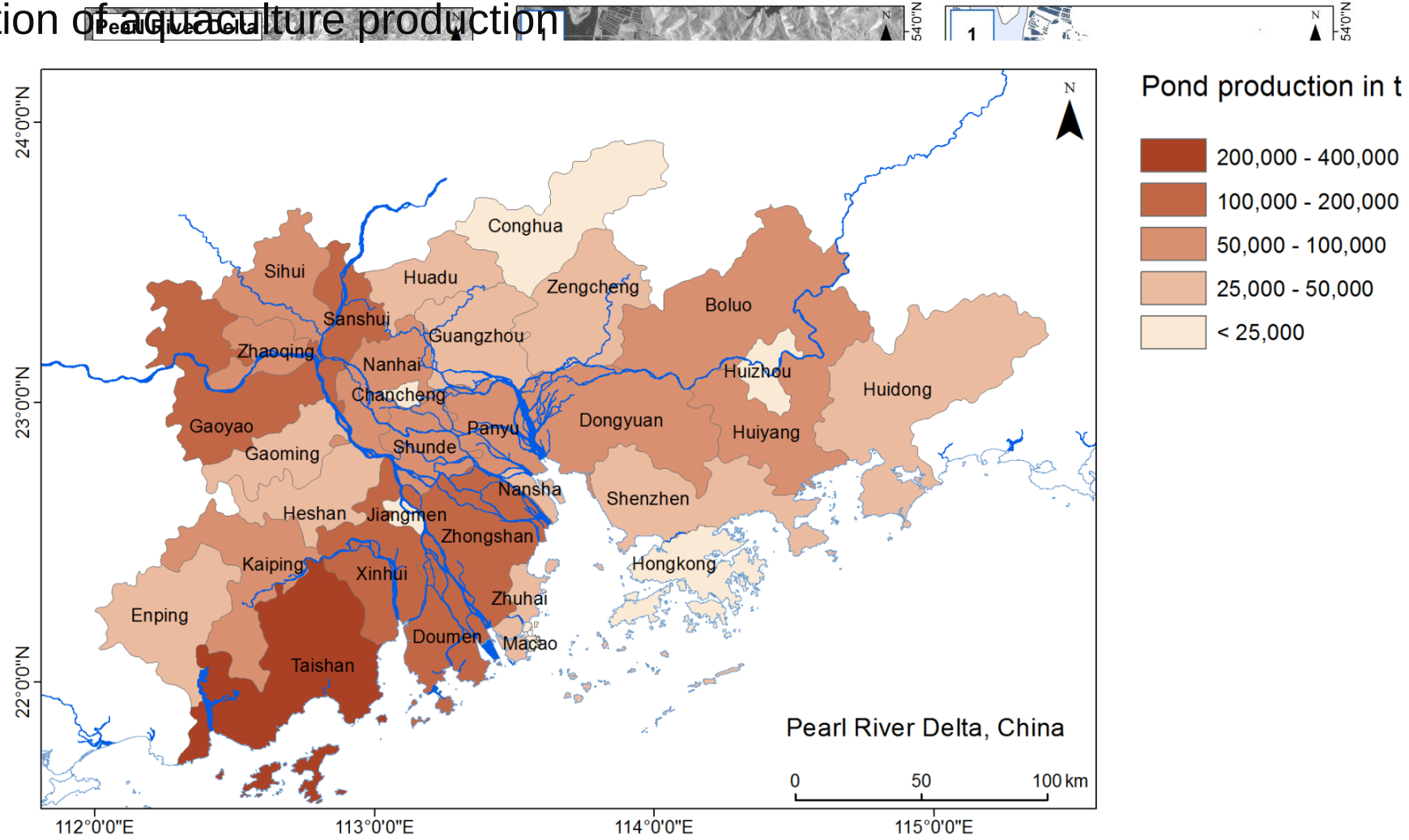


Dissertation zur Erlangung der Doktorwürde der naturwissenschaftlichen Fakultät der Julius-Maximilians-Universität Würzburg

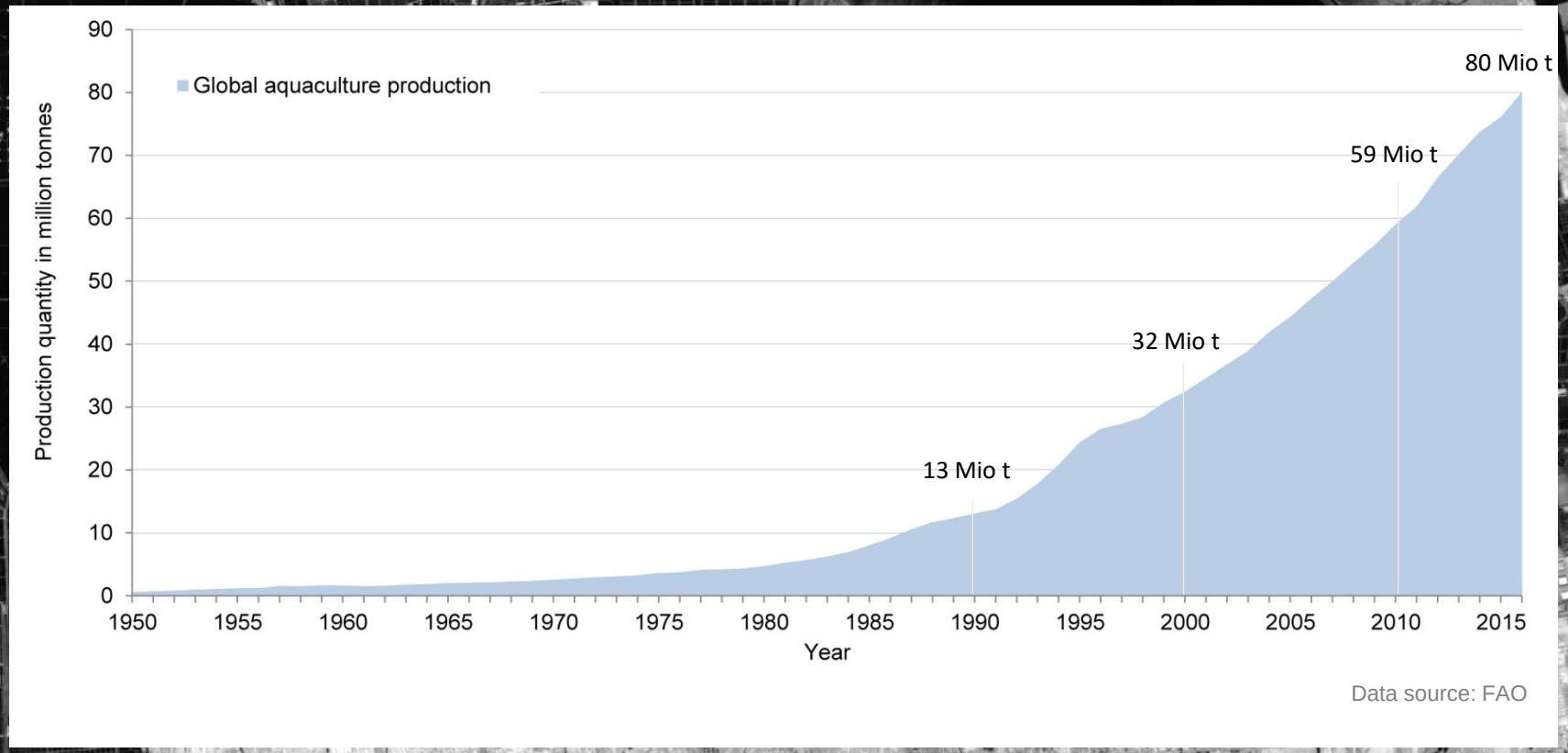
vorgelegt von
Marco Maximilian Ottinger

What can Earth Observation do?

1. Detection of aquaculture ponds with Sentinel-1 time series data
2. Estimation of aquaculture production



Aquaculture Dynamics Yellow River Delta, China



1984

↓

1995

↓

2004

↓

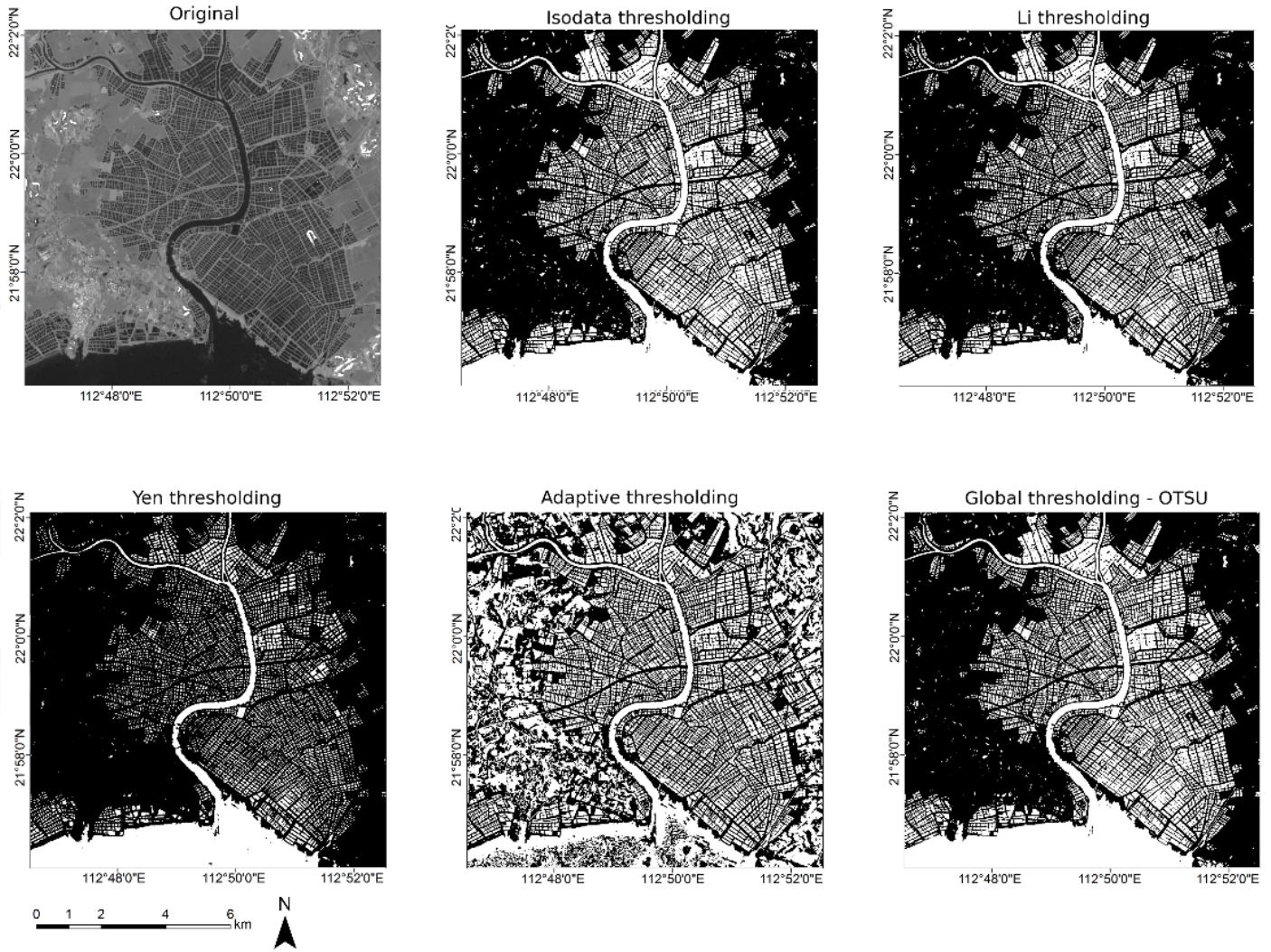
2014

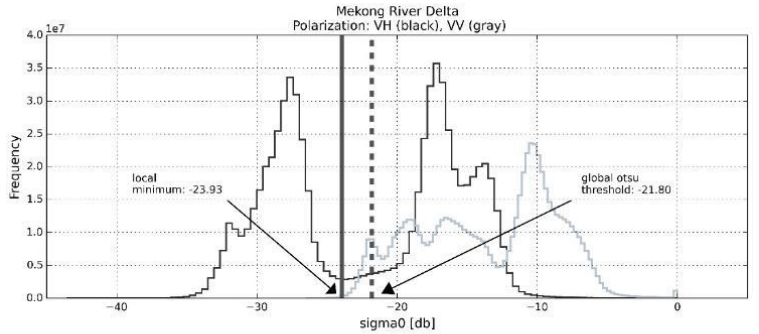
Source: Ottinger, M., Clauss, K., Kuenzer, C. (2016): Aquaculture: Relevance, distribution, impacts and spatial assessments – A review. Ocean & Coastal Management, 119, 244-266.

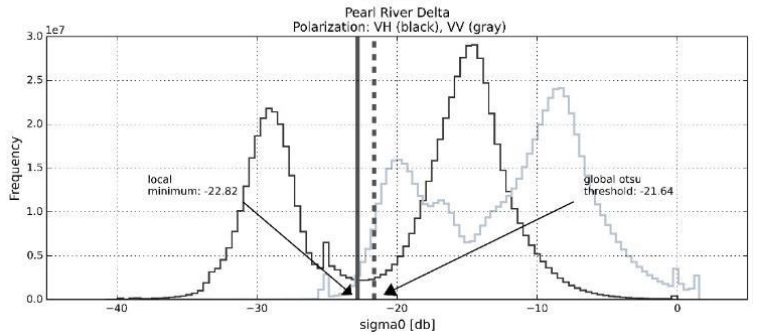
0 5 10 km

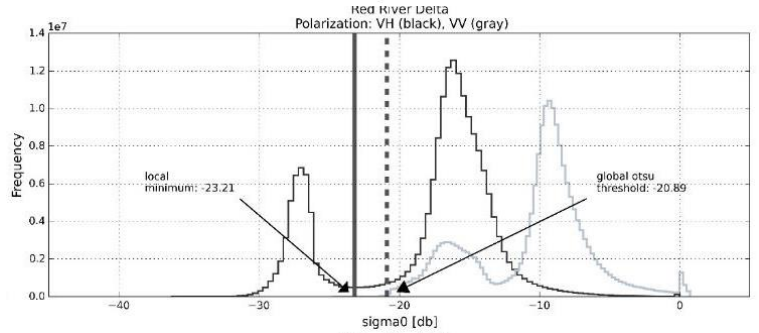
Methodology

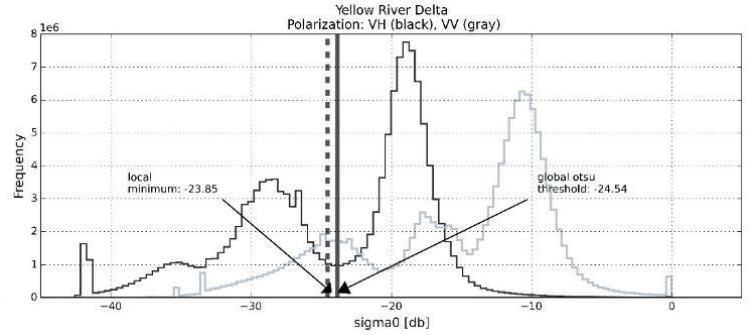
Water thresholding











Source: Ottinger et al. (2017): Large-scale assessment of coastal aquaculture ponds with Sentinel-1 time series data. *Remote Sensing*, 9(5).

Advantages of SAR Time Series Data

Rice field

Salt fields

Aquaculture ponds

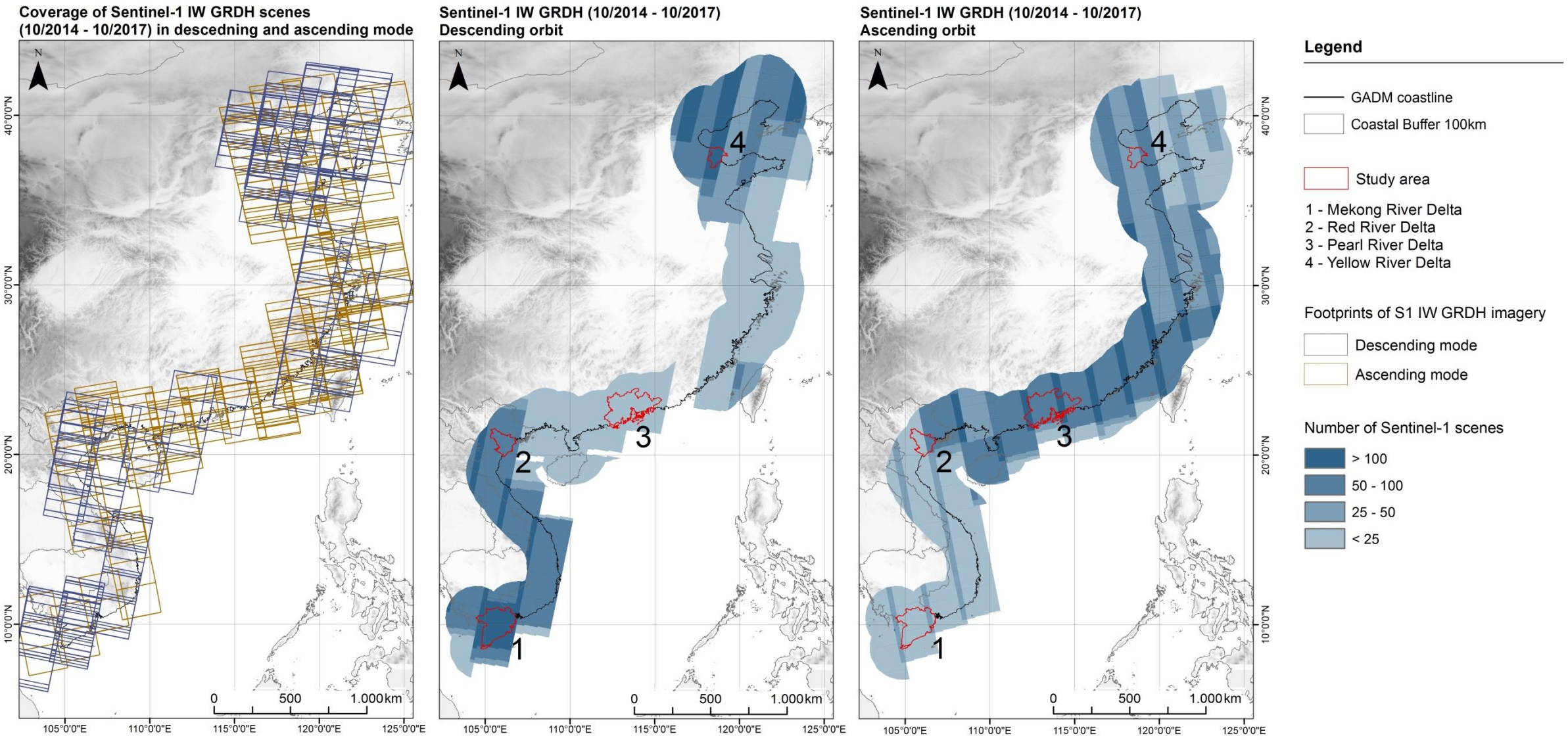
Aquaculture:
- Rectangle
- Water
- Dikes

- **PERMANENT !**

backscatter characteristic of water surfaces (ponds)

free and open data policy

Sentinel-1 Data Coverage



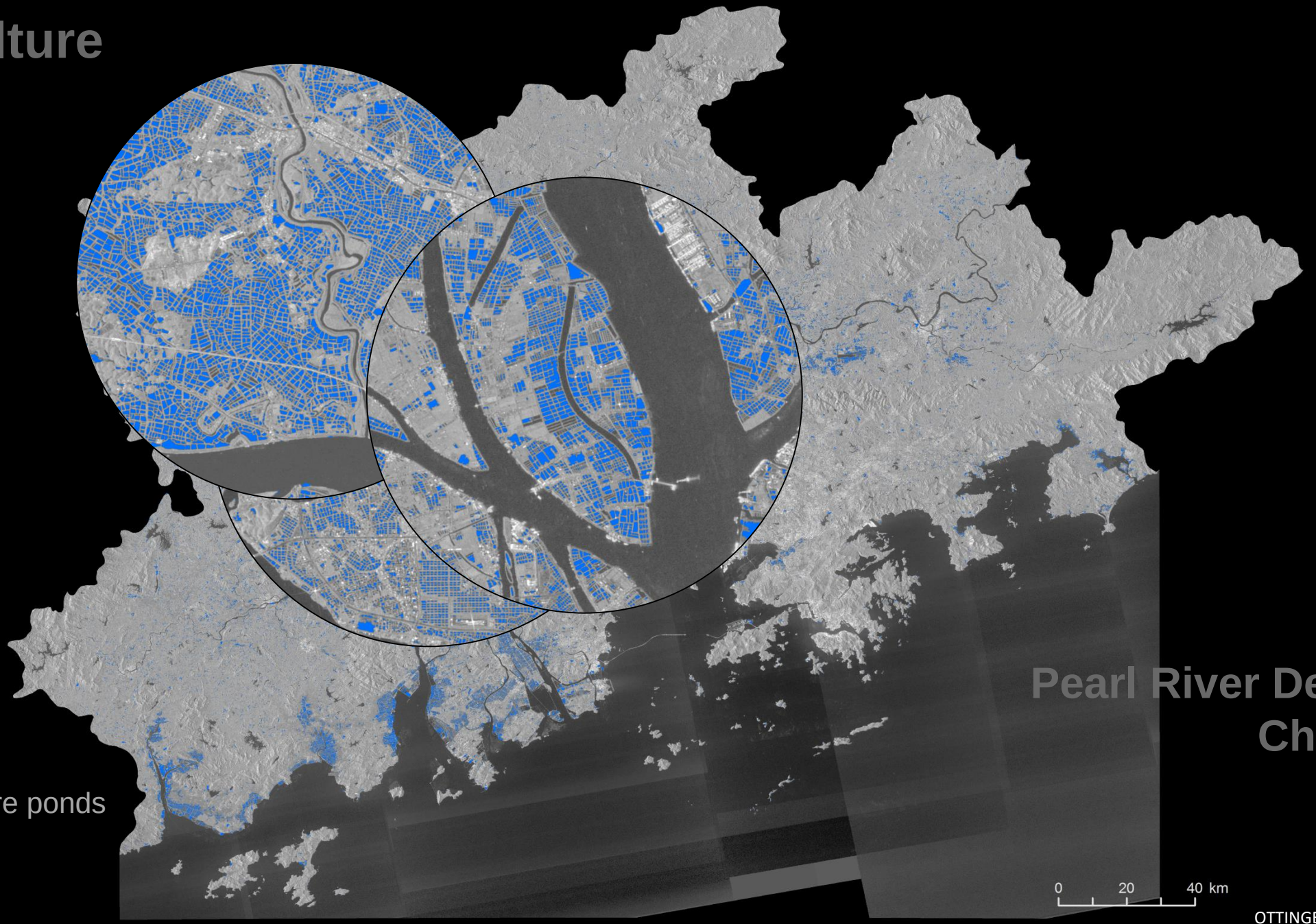
Aquaculture

Aquaculture ponds

Mekong Delta
Vietnam

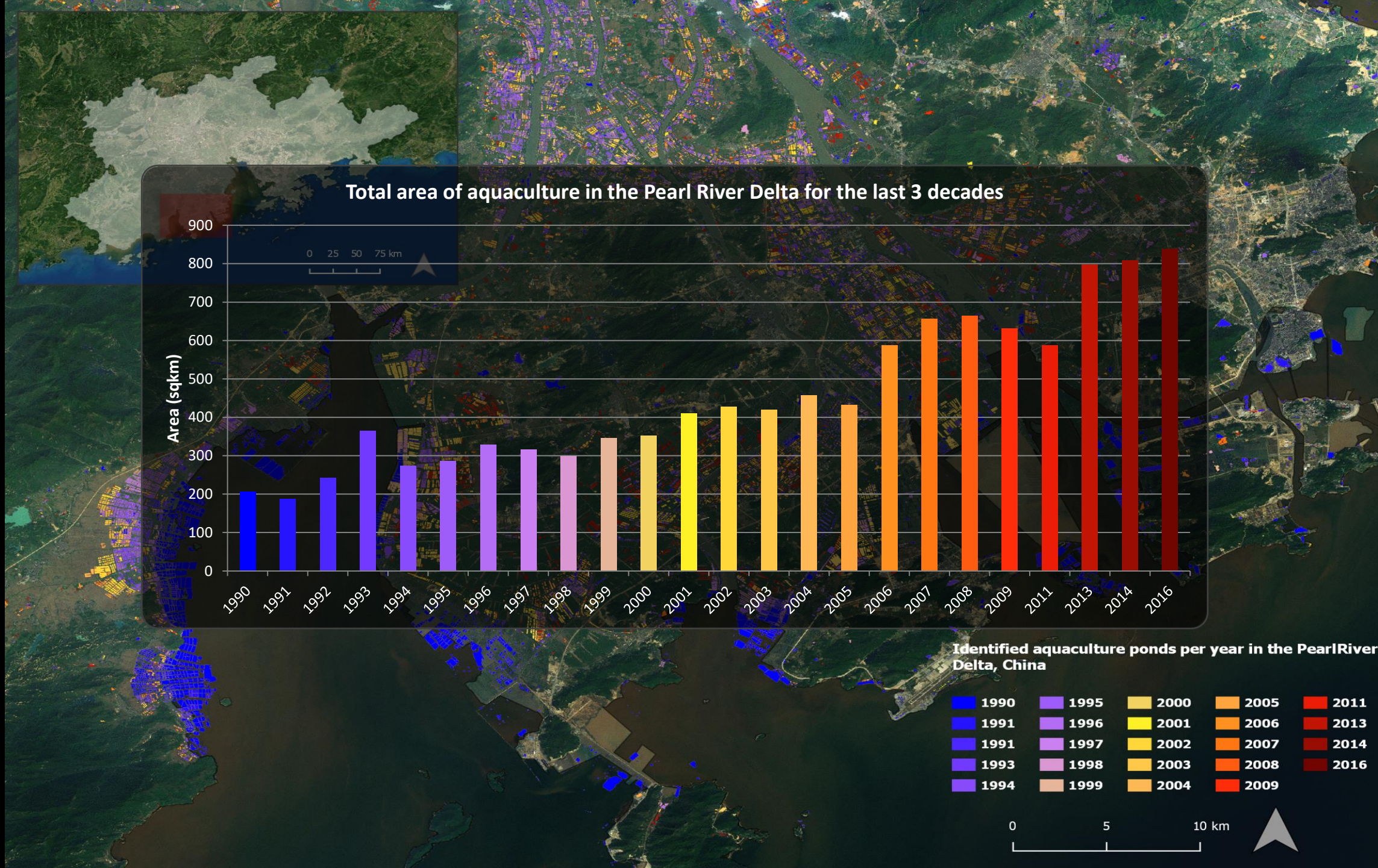
OTTINGER M. et al. (2017)

Aquaculture



OTTINGER M. et al. (2017)

Aquaculture Pearl River Delta



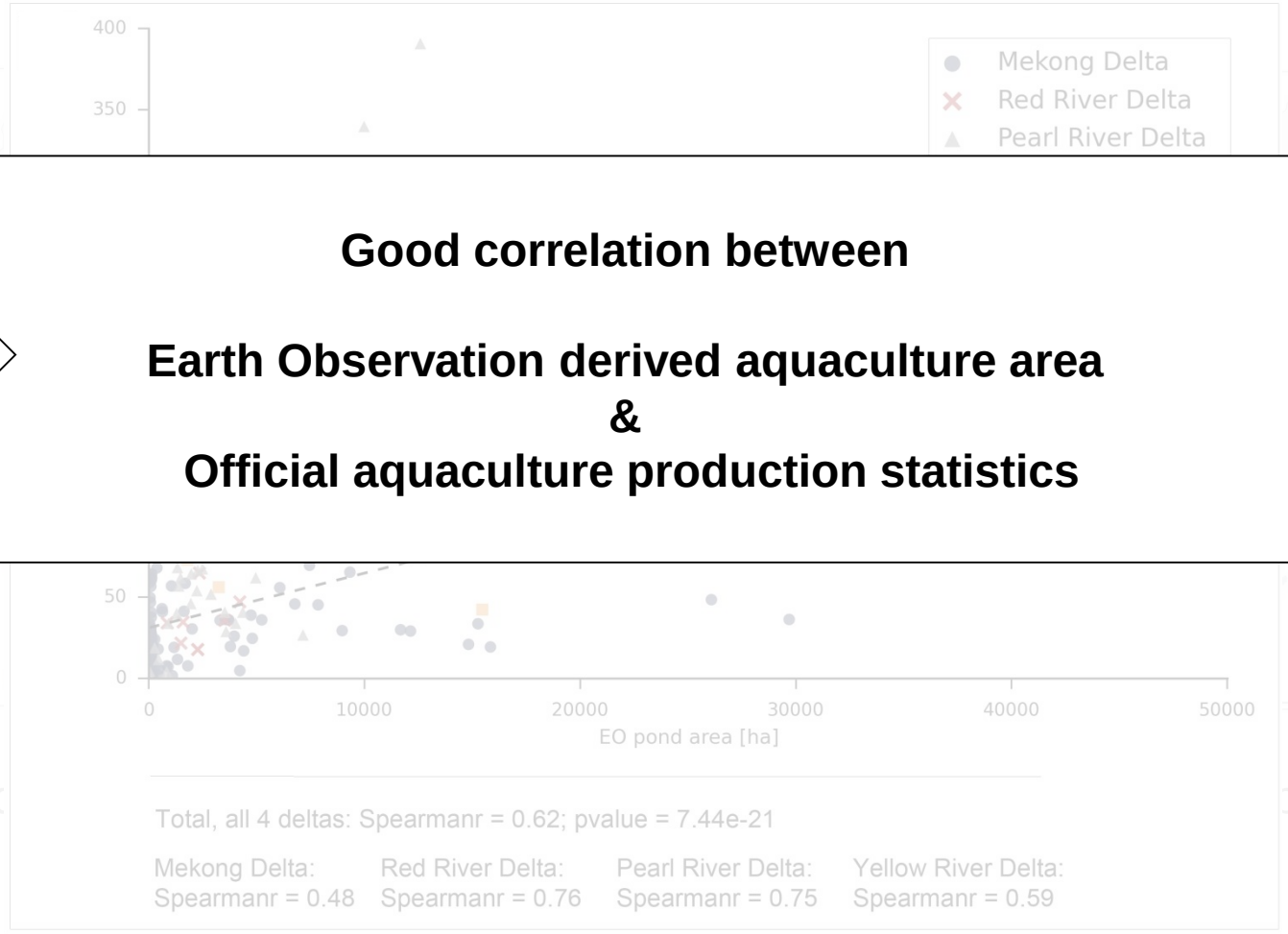
EO-based Estimation of Aquaculture Production

- Estimation of aquaculture production from Earth Observation data
- Relationship: pond size / stocking density

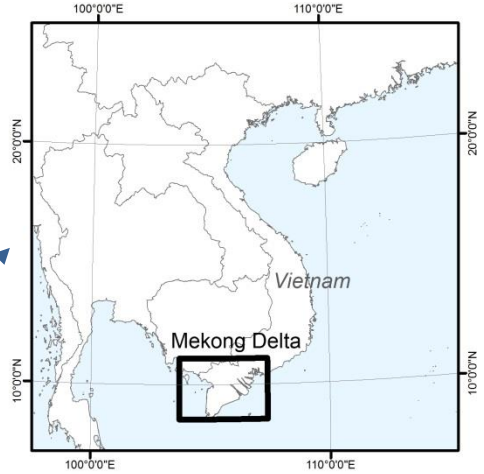
EO-derived Aquaculture & Production Statistics

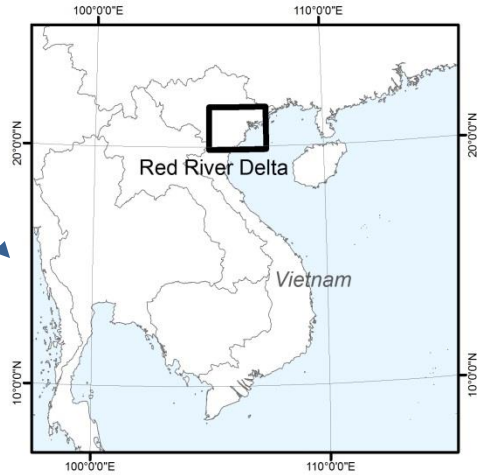
Good correlation between

Earth Observation derived aquaculture area
&
Official aquaculture production statistics

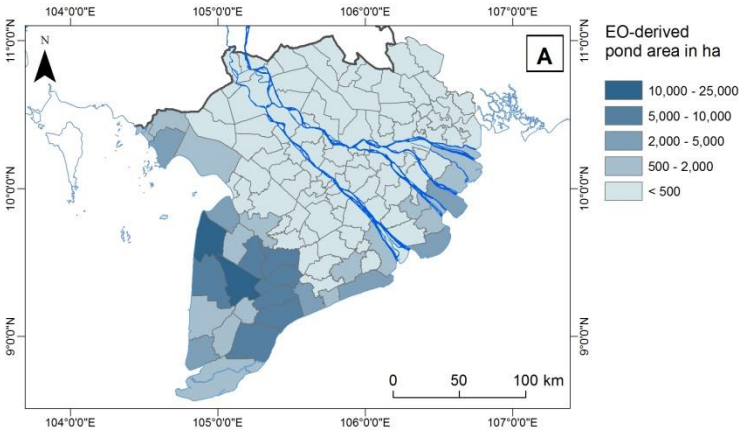


Estimation of Aquaculture Production

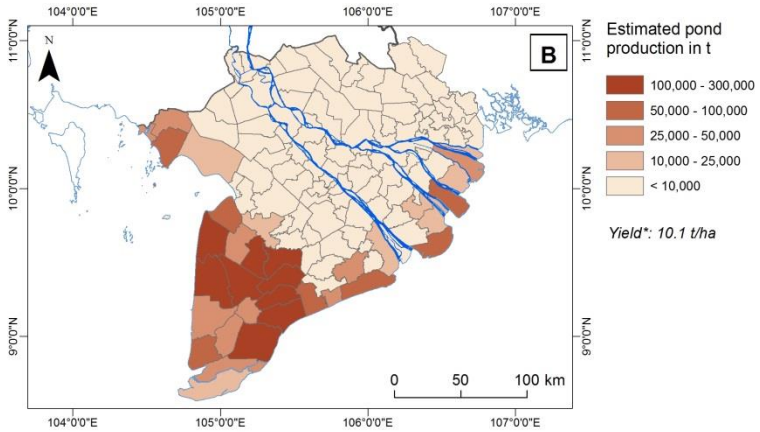




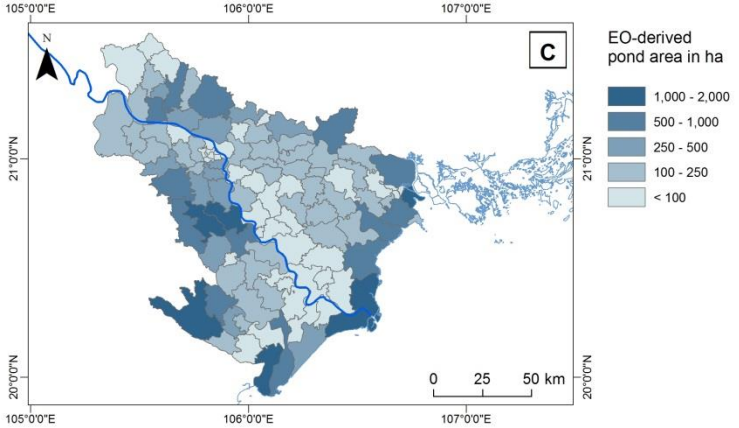
Mekong Delta - EO-derived pond area per district



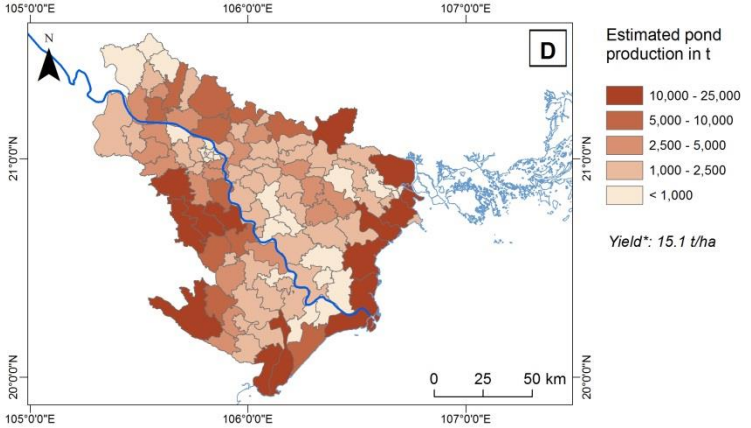
Mekong Delta - Estimated pond production per district



Red River Delta - EO-derived pond area per district

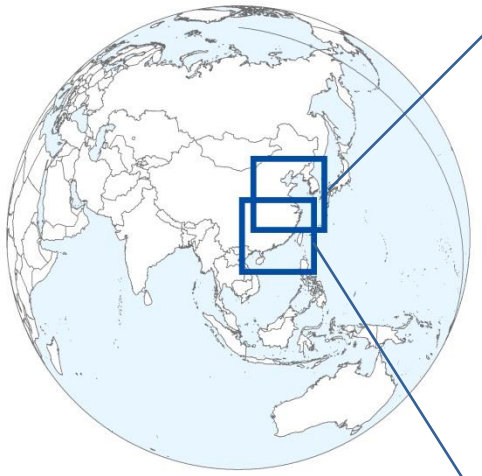


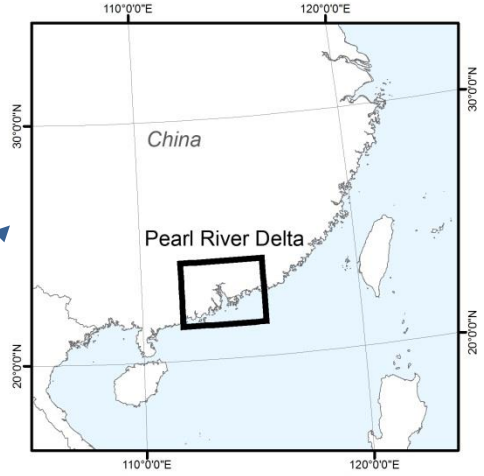
Red River Delta - Estimated pond production per district

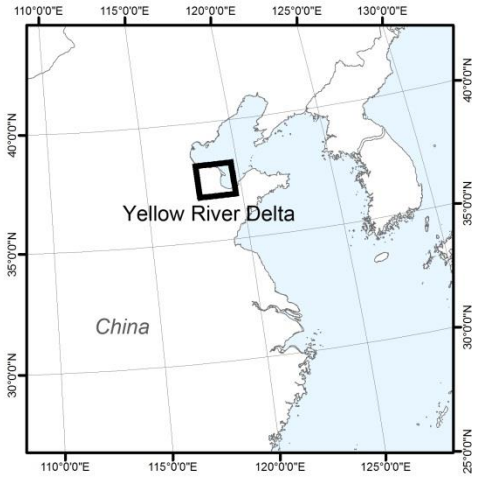


OTTINGER M. et al. (2018)

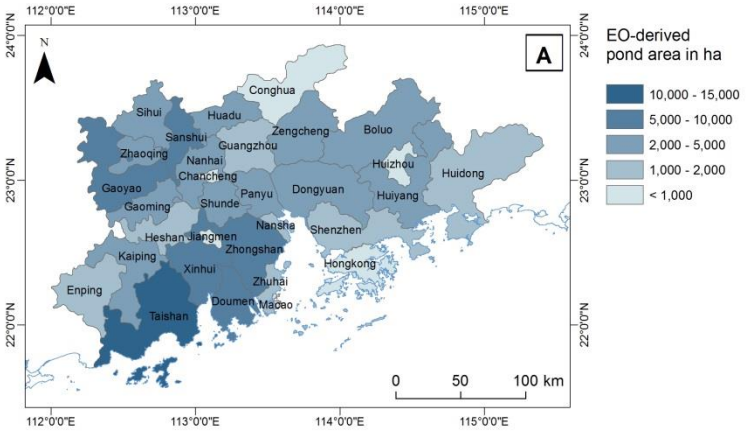
Estimation of Aquaculture Production



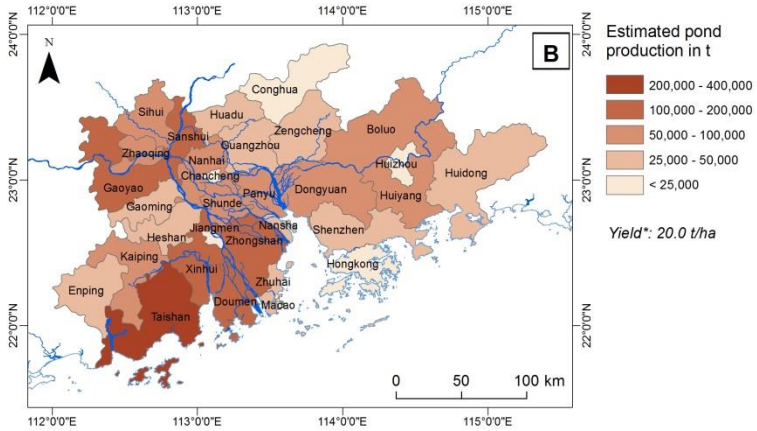




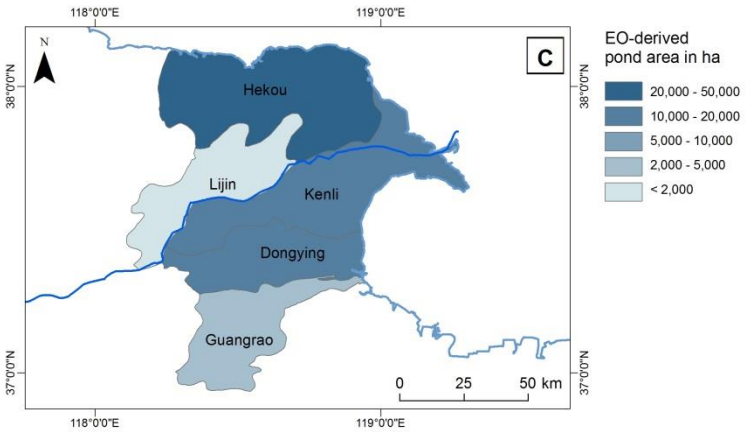
Pearl River Delta - EO-derived pond area per county



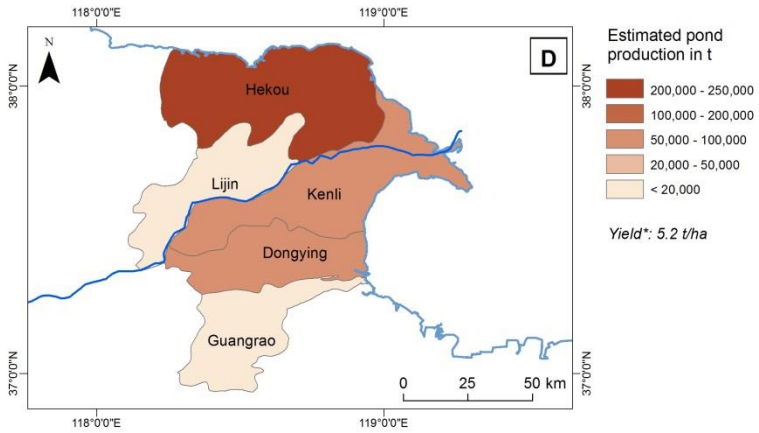
Pearl River Delta - Estimated pond production per county



Yellow River Delta - EO-derived pond area per county



Yellow River Delta - Estimated pond production per county



OTTINGER M. et al. (2018)

Thank you for your interest!

marco.ottinger@dlr.de