

DATA PAPER

VBORNET Gap Analysis: Sand Fly Vector Distribution Models Utilised to Identify Areas of Potential Species Distribution in Areas Lacking Records

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This is the first of a number of planned data papers presenting modelled vector distributions, the models in this paper were produced during the ECDC funded VBORNET project. This work continues under the VectorNet project now jointly funded by ECDC and EFSA. This data paper contains the sand fly model outputs produced as part of the VBORNET project. Further data papers will be published after sampling seasons when more field data will become available allowing further species to be modelled or validation and updates to existing models.

The data package described here includes those sand fly species first modelled in 2013 and 2014 as part of the VBORNET gap analysis work which aimed to identify areas of potential species distribution in areas lacking records. It comprises four species models together with suitability masks based on land class and environmental limits. The species included within this paper are *Phlebotomus ariasi*, *Phlebotomus papatasi*, *Phlebotomus perniciosus* and *Phlebotomus tobbi*.

The known distributions of these species within the project area (Europe, the Mediterranean Basin, North Africa, and Eurasia) are currently incomplete to a greater or lesser degree. The models are designed to fill the gaps with predicted distributions, to provide a) assistance in targeting surveys to collect distribution data for those areas with no field validated information, and b) a first indication of project wide distributions.

Keywords: VBORNET; Sand flies; species; distribution; habitat; Non-Linear Discriminant Analysis; Random Forest; Generalised Linear Modelling

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1. Overview

Introduction/Study Description

VBORNET [1] was an initiative of the European Centre for Disease Prevention and Control (ECDC), which ran from 2009 to 2014. The project established a European network of entomological and public health specialists in order to assist ECDC in its preparedness activities on vector-borne diseases (VBD). As part of this work a database collating validated records of key species distributions were commissioned. This data paper focusses on four sand fly species *Phlebotomus ariasi*, *Phlebotomus papatasi*, *Phlebotomus perniciosus* and *Phlebotomus tobbi* vectors of *Leishmaniasis*.

VectorNet [2] has continued this work and builds upon VBORNET by supporting the collection of data on vectors and pathogens in vectors, related to both animal and human health. VectorNet is a joint initiative of the European Food Safety Authority (EFSA) and the European Centre for Disease Prevention and Control (ECDC), which started in May 2014.

Whilst VBORNET and VectorNet have made substantial progress collating European data on key vector species, the coverage is still incomplete. The 'Gap Analysis' work within these projects aims to identify those areas of likely species distribution within the project extent where there are no current data. These estimates produced by

spatial modelling techniques are intended to meet two objectives: firstly to help direct extensive VectorNet sampling efforts in the field; and secondly to provide first indications of the current likely extent and distribution of key vector species within continental Europe and its surrounding regions. It is hoped that publishing these models will aid the VectorNet network of experts to engage the wider research and professional community in the drive to expand and validate the VectorNet database. Readers are encouraged to contact the authors or visit the VectorNet website [2].

For each species probability of presence maps at the resolution of 1km were generated using a variety of well-established spatial modelling techniques available through the VECMAP system [3]. Both the input data and the resulting models were iteratively assessed by project experts and the best performing are included in this data package.

2. Context

Spatial coverage

Description: Continental Europe

Northern boundary: 71.8

Southern boundary: 33.5

Eastern boundary: 62.3

Western boundary: -11.2

Temporal coverage

Known presence up to (31/01/2013).

Species

Phlebotomus ariasi vector of *Leishmania infantum* and *phleboviruses*.

Phlebotomus papatasi vector of *Leishmania major* and *phleboviruses*.

Phlebotomus perniciosus vector of *Leishmania infantum* and *phleboviruses*.

Phlebotomus tobbi vector of *Leishmania infantum*, *Leishmania donovani* and *phleboviruses*.

3. Methods

For each of the species the following method was followed.

Steps

Identifying presence and absence training data

The reported distributions of each of the four sand fly species by VBORNET were used as the basis for species present training data for the analysis. Data reported from the VBORNET map published January 2013 were used for *Phlebotomus perniciosus* and *Phlebotomus tobbi*, and January 2014 for *Phlebotomus ariasi* and *Phlebotomus papatasi*. Maps of the recorded known distributions at that time are presented in Appendix 1 available within this data package. These reported distributions were recorded in VBORNET at a coarse NUTS 3 polygon scale. The data originates from a combination of both aggregated data contributed by the authors and listed contributors. As well as a literature review completed by the VBORNET vector group leaders. The full data set and

sources are available to contributors of VBORNET and VectorNet.

Habitat suitability and environmental limits

The recorded distributions were too coarse to be utilised by the model framework. In addition, the selected modelling methods required information on both presence and absence to calibrate the modelling process. It was therefore necessary to identify areas of absence within NUTS 3 regions assigned as present. To do this a suitability mask at 1 km resolution was compiled by requesting experts within the network (see the Data Creators section) to identify primary, secondary and unsuitable land cover classes. For the phase two models (*Ph. ariasi* and *Ph. papatasi*) environmental limiting factors which are derived from remotely sensed imagery were also identified and used in the mask.

Environmental limits masks were created using altitude measures and temperature limits derived from the SRTM 100m Digital Elevation Model [4] and BIOCLIM [5] temperature layers respectively. *Phlebotomus ariasi* limits were set as the minimum altitude within a 1km square must be below 1700m. While the temperature limits were using the BIOCLIM Tmax layer between 15–32 degrees centigrade. For *Ph. papatasi* minimum altitude limits must be below 2000m and between 20–30 degrees centigrade using the BIOCLIM Tmean layer. Whilst these values are loosely based on laboratory findings (Personal communication with Ozge Erisoz Kasap – See Data contributors) the values were assessed visually and calibrated to account for differences between laboratory measurements of species behaviour and recorded remotely sensed values at coarse resolution.

The land cover masks were defined utilising the 100m Corine land cover dataset [6] and the 300m GLOBCOVER [7] product where no Corine data was available. Definitions of land class suitability for each species as defined by experts can be found in **Tables 1** and **2**.

Modelling procedure

A range of modelling techniques available in the VECMAP [3] system including Non Linear Discriminant Analysis [8], Logistic Regression [9] and Random Forests [10], using 10–25 repeated bootstraps per run, were used to provide a range of outputs for expert assessment.

The covariates offered to the modelling procedures were drawn from a standardised set of ecological parameters, and in particular a suite of Fourier processed MODIS satellite imagery [11] which provides a range of biologically interpretable variables related to levels and seasonality of temperature and vegetation related factors during the period 2000–2012. These are summarised in **Table 3**, and are all available to registered members of the VMerge/EDENext Data Website (www.vmergedata.com) [12].

Output layers

The suitability masked modelled outputs are produced in the form of probability maps at the pixel level with a resolution of 1 kilometre for each species. Quick view

CORINE LABEL	PHTO	PHPE	PHAR	PHPA
Continuous urban fabric	0	0	0	1
Discontinuous urban fabric	0	0	0	1
Industrial or commercial units	0	0	0	1
Road and rail networks and associated land	0	0	0	1
Port areas	0	0	0	1
Airports	0	0	0	1
Mineral extraction sites	0	0	0	1
Dump sites	0	0	0	1
Construction sites	1	1	1	1
Green urban areas	1	1	1	1
Sport and leisure facilities	0	0	0	1
Non-irrigated arable land	1	1	1	1
Permanently irrigated land	1	1	1	1
Rice fields	1	0	0	1
Vineyards	1	1	1	1
Fruit trees and berry plantations	1	1	1	1
Olive groves	1	1	1	1
Pastures	1	0	0	1
Annual crops associated with permanent crops	1	1	1	1
Complex cultivation patterns	1	1	1	1
Land principally occupied by agriculture, with significant areas of natural vegetation	1	1	1	1
Agro-forestry areas	1	1	1	1
Broad-leaved forest	1	1	1	0
Coniferous forest	1	1	1	1
Mixed forest	1	1	1	1
Natural grasslands	1	0	0	1
Moors and heathland	1	1	1	1
Sclerophyllous vegetation	1	1	1	1
Transitional woodland-shrub	1	1	1	1
Beaches, dunes, sands	0	0	0	0
Bare rocks	1	1	1	0
Sparsely vegetated areas	0	1	1	1
Burnt areas	0	0	0	0
Glaciers and perpetual snow	0	0	0	0
Inland marshes	0	0	0	0
Peat bogs	0	0	0	0
Salt marshes	0	0	0	0
Salines	0	0	0	0
Intertidal flats	0	0	0	0
Water courses	0	0	0	0
Water bodies	0	0	0	0
Coastal lagoons	0	0	0	0
Estuaries	0	0	0	0
Sea and ocean	0	0	0	0

Table 1: Reclassed values defining the Corine [6]. suitability layers 1 = suitable and 0 = unsuitable. PHPE = *Phlebotomus perniciosus*, PHTO = *Phlebotomus tobbi*, PHAR = *Phlebotomus ariasi* and PHPA = *Phlebotomus papatasi*.

GLOBCOVER LABEL	PHTO	PHPE	PHAR	PHPA
Post-flooding or irrigated croplands (or aquatic)	1	0	0	1
Rainfed croplands	1	0	0	1
Mosaic cropland (50–70%) / vegetation (grassland/shrubland/forest) (20–50%)	1	1	1	1
Mosaic vegetation (grassland/shrubland/forest) (50–70%) / cropland (20–50%)	1	1	1	1
Closed to open (>15%) broadleaved evergreen or semi-deciduous forest (>5m)	1	1	1	1
Closed (>40%) broadleaved deciduous forest (>5m)	1	1	1	1
Open (15–40%) broadleaved deciduous forest/woodland (>5m)	1	1	1	1
Closed (>40%) needleleaved evergreen forest (>5m)	1	1	1	1
Open (15–40%) needleleaved deciduous or evergreen forest (>5m)	1	1	1	1
Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)	1	1	1	1
Mosaic forest or shrubland (50–70%) / grassland (20–50%)	1	1	1	1
Mosaic grassland (50–70%) / forest or shrubland (20–50%)	1	1	1	1
Closed to open (>15%) (broadleaved or needleleaved, evergreen or deciduous) shrubland (<5m)	0	1	1	1
Closed to open (>15%) herbaceous vegetation (grassland, savannas or lichens/mosses)	0	1	1	1
Sparse (<15%) vegetation	0	1	1	1
Closed to open (>15%) broadleaved forest regularly flooded (semi-permanently or temporarily) – Fresh or brackish water	0	0	0	0
Closed (>40%) broadleaved forest or shrubland permanently flooded – Saline or brackish water	0	0	0	0
Closed to open (>15%) grassland or woody vegetation on regularly flooded or waterlogged soil – Fresh, brackish or saline water	0	0	0	0
Artificial surfaces and associated areas (Urban areas >50%)	1	1	1	1
Bare areas	0	0	0	0
Water bodies	0	0	0	0
Permanent snow and ice	0	0	0	0
No data (burnt areas, clouds, . . .)	0	0	0	0

Table 2: Reclassed values defining the Globcover [7]. suitability layers 1 = suitable and 0 = unsuitable. PHPE = *Phlebotomus perniciosus*, PHTO = *Phlebotomus tobbi*, PHAR = *Phlebotomus ariasi* and PHPA = *Phlebotomus papatasi*.

for each vector species is available to view in Appendix 2 available within this data package.

Sampling strategy

Training sample point data for the model was extracted as follows:

- Random present points were created from any area within a NUTS 3 polygon recorded as present and where the suitability masked did not indicate unsuitability.
- Random absence points were selected areas from identified in the mask as unsuitable.

Quality Control

The model outputs were initially evaluated using the standard, and extensive, accuracy metrics (e.g. R-squared, AIC, Kappa, Confusion matrices) provided by the VECMAP [3] software. Providing the accuracy metrics indicated sufficient statistical reliability. The range of models were

then sent to selected experts who were asked to choose from the selection provided. Experts included individuals listed in the Data Creator section of this paper.

In the first phase of modelling (*Ph. perniciosus* and *Ph. tobbi*) the best model selected by the experts was used as the final model for that species. During phase 2 of the modelling (*Ph. ariasi* and *Ph. Papatasi*), ensembles of the different model techniques were preferred to attempt to iron out any inherent bias within individual modelling methods. Naturally if a model was not approved by the network experts it was not included in the ensemble.

Ground truthing has yet to be completed on these models although fieldwork has been subsequently sponsored by the VectorNet project which will visit areas which have been modelled, but currently have no data available. So retrospective quality assessments should be completed in the future.

1 ED1803A0: Middle infra-red mean	38 ED1814P2: NDVI phase 2
2 ED1803A1: Middle infra-red amplitude 1	39 ED1814P3: NDVI phase 3
3 ED1803A2: Middle infra-red amplitude 2	40 ED1814VR: NDVI variance
4 ED1803A3: Middle infra-red amplitude 3	41 ED1815A0: EVI mean
5 ED1803MN: Middle infra-red minimum	42 ED1815A1: EVI amplitude 1
6 ED1803MX: Middle infra-red maximum	43 ED1815A2: EVI amplitude 2
7 ED1803P1: Middle infra-red phase 1	44 ED1815A3: EVI amplitude 3
8 ED1803P2: Middle infra-red phase 2	45 ED1815MN: EVI minimum
9 ED1803P3: Middle infra-red phase 3	46 ED1815MX: EVI maximum
10 ED1803VR: Middle infra-red variance	47 ED1815P1: EVI phase 1
11 ED1807A0: Daytime LST mean	48 ED1815P2: EVI phase 2
12 ED1807A1: Daytime LST amplitude 1	49 ED1815P3: EVI phase 3
13 ED1807A2: Daytime LST amplitude 2	50 ED1815VR: EVI variance
14 ED1807A3: Daytime LST amplitude 3	51 EDBC2K12: BioClim Annual Precipitation
15 ED1807MN: Daytime LST minimum	52 EDBC2K13: BioClim Precipitation of Wettest Month
16 ED1807MX: Daytime LST maximum	53 EDBC2K14: BioClim Precipitation of Driest Month
17 ED1807P1: Daytime LST phase 1	54 EDBC2K15: BioClim Precipitation Seasonality (Coefficient of Variation)
18 ED1807P2: Daytime LST phase 2	55 EDBC2K16: BioClim Precipitation of Wettest Quarter
19 ED1807P3: Daytime LST phase 3	56 EDBC2K17: BioClim Precipitation of Driest Quarter
20 ED1807VR: Daytime LST variance	57 EDBC2K18: BioClim Precipitation of Warmest Quarter
21 ED1808A0: Nighttime LST mean	58 EDBC2K19: BioClim Precipitation of Coldest Quarter
22 ED1808A1: Nighttime LST amplitude 1	59 EDV590AS: DEM (Aspect)
23 ED1808A2: Nighttime LST amplitude 2	60 EDV590EL: DEM (Elevation)
24 ED1808A3: Nighttime LST amplitude 3	61 EDV590RG: DEM (Ruggedness)
25 ED1808MN: Nighttime LST minimum	62 EDWC57A0: WORLDCLIM precipitation mean
26 ED1808MX: Nighttime LST maximum	63 EDWC57A1: WORLDCLIM precipitation amplitude 1
27 ED1808P1: Nighttime LST phase 1	64 EDWC57A2: WORLDCLIM precipitation amplitude 2
28 ED1808P2: Nighttime LST phase 2	65 EDWC57A3: WORLDCLIM precipitation amplitude 3
29 ED1808P3: Nighttime LST phase 3	66 EDWC57MN: WORLDCLIM precipitation minimum
30 ED1808VR: Nighttime LST variance	67 EDWC57MX: WORLDCLIM precipitation maximum
31 ED1814A0: NDVI mean	68 EDWC57P1: WORLDCLIM precipitation phase 1
32 ED1814A1: NDVI amplitude 1	69 EDWC57P2: WORLDCLIM precipitation phase 2
33 ED1814A2: NDVI amplitude 2	70 EDWC57P3: WORLDCLIM precipitation phase 3
34 ED1814A3: NDVI amplitude 3	71 EDWC57VR: WORLDCLIM precipitation variance
35 ED1814MN: NDVI minimum	72 EDXXGRPD: GRUMP Population density
36 ED1814MX: NDVI maximum	73 EDXXGRPW: GRUMP Population weighted
37 ED1814P1: NDVI phase 1	74 EDXXJRCA: JRC Access
	75 EDXXLP1: Length of Growing Period LGP

LST = Land Surface Temperature. NDVI Normalised Difference vegetation Index; EVI Enhanced Vegetation Index. DEM Digital Elevation. All files starting with ED18 are Fourier processed MODIS Satellite Imagery produced by the TALA research Group Oxford [11].

Files with Bioclim and Worldclim in filename derived from WORLDCLIM datasets [5].

GRUMP derived from population layers produced by [13].

JRC Accessibility downloaded from [14].

Length of growing Period derived from data provided by FAO, Rome. Available from www.vmerge.com [12].

All layers extracted and standardised by ERGO for EDENext (www.edenextdata.com) [15].

Table 3: Covariates offered to modelling procedures.

Constraints

There were no constraints in the data production.

Privacy

N/A.

Ethics

N/A.

4. Dataset description

Object name

<https://dx.doi.org/10.6084/m9.figshare.3426065>

Data type

Processed data; Interpretation of data.

Ontologies

N/A.

Format names and versions

JPG, JP2, TIF, TFW, XML.

Creation dates

The start and end dates of when the data was created (13/04/2013).

Dataset creators

The contributors listed in the table below all contributed data into the VBORNET database for one or all of the species detailed in this paper. Bulent Alten and Ozge Erisoz Kasap were key in defining the unsuitable habitat and

environmental limits used in the input suitability masks. While Bulent Alten's extensive experience of research in the field of Phlebotomines in and around Europe were extremely useful when assessing the maps and the success of the model outputs.

Contributor	Affiliation
Alten, Bulent	Hacettepe University, Ankara, Turkey
Dikolli, Enkelejda	Institute of Public Health, Tirana, Albania
Falcuta, Elena	Cantacuzino Institute, Bucharest, Romania
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Hendrickx, Guy	Avia-GIS, Belgium
Ivovic, Vladimir	University of Primorska, Koper, Slovenia
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Kasap, Ozge Erisoz	Hacettepe University, Ankara, Turkey
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Pajovic, Igor	University of Montenegro, Biotechnical Faculty, Montenegro
Petric, Dusan	Faculty of Agriculture, University of Novi Sad, Serbia
Saska, Aleksandra	Science and Research Center, Koper, Slovenia
Schaffner, Francis	Consultancy, France
Sousa, Carla A.	Instituto de Higiene e Mdecina Tropical, Lisbon, Portugal
Zygotiene, Milda	Centre for Communicable diseases and AIDS, Vilnius, Lithuania

Language
English.

Programming language
N/A.

Licence
The open licence under which the data has been deposited CC-BY.

Accessibility criteria
The data are distributed as GIS raster GeoTIFF formats. Which is a standard proprietary GIS raster format. To access and analyse the raster data directly GeoTIFFs can

be read by most GIS software and some other software packages. These formats are compatible with proprietary (ESRI ArcGIS) and open source Quantum GIS (QGIS) or R-project raster package). If the user has no suitable software already installed the authors suggest downloading the open source QGIS software free of charge from <http://www.qgis.org> to view these data.

A simple schematic of the data layers and directories found within this data package is shown below with descriptions where filenames are not self-explanatory:

- **Appendices** – Directory containing the appendices for this document.
 - **ohd_VBNPhBD_AltenEtAl_Appendix1.pdf**
 - **ohd_VBNPhBD_AltenEtAl_Appendix2.pdf**
- **Quickview** – Directory containing small JPEG files allowing the reader to view the data visually without specialist software.
 - **appendix1mapsPHAR.jpg** – VBORNET Status *Phlebotomus ariasi*
 - **appendix1mapsPHPA.jpg** – VBORNET Status *Phlebotomus papatasi*
 - **appendix1mapsPHPE.jpg** – VBORNET Status *Phlebotomus perniciosus*
 - **appendix1mapsPHTO.jpg** – VBORNET Status *Phlebotomus tobbi*
 - **appendix2mapsPHAR.jpg** – Model output *Phlebotomus ariasi*
 - **appendix2mapsPHPA.jpg** – Model output *Phlebotomus papatasi*
 - **appendix2mapsPHPE.jpg** – Model output *Phlebotomus perniciosus*
 - **appendix2mapsPHTO.jpg** – Model output *Phlebotomus tobbi*
- **Tiff** – Directory containing model output data for display and interrogation within GIS and geostatistical software.*
 - **pharMskense.tif** – Model output *Phlebotomus ariasi*
 - **phpaMskense.tif** – Model output *Phlebotomus papatasi*
 - **phpemodelMsk.tif** – Model output *Phlebotomus perniciosus*
 - **phtomodelMsk.tif** – Model output *Phlebotomus tobbi*

*Only the tif files within this directory are listed. Other file formats of the same name within the directory are ancillary files that provide additional data to the GIS software and as a rule should be copied along with the TIFF file of the same name if you are moving the data between directories.

Repository location
<https://dx.doi.org/10.6084/m9.figshare.3426065>

Publication date
If already known, the date the dataset was published in the repository (23/08/2016).

5. Reuse potential

These layers have been created in an attempt to identify probable areas of species distribution where there are currently no sample data. These maps therefore could be useful in identifying suitable areas for further sampling in an attempt to identify the true distribution of the species. The VectorNet project plans to utilise these datasets in such a way.

The covariates of the models are also mainly climate orientated. A possible avenue of further work therefore could be to use the models to assess the potential change in distribution after a shift in climate parameters.

Additional Files

The additional files for this article can be found as follows:

- **Additional File 1: Appendix 1.** VBORNET Reported Distributions 2013 & 2014. <http://dx.doi.org/10.5334/ohd.26.s1>
- **Additional File 2: Appendix 2.** VBORNET model output quick view. <http://dx.doi.org/10.5334/ohd.26.s2>

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Competing Interests

The authors have no competing interests to declare.

References

1. **VBORNET Website** Available from: <http://www.vbornet.eu/>.
2. **VectorNet Website** Available from: <http://ecdc.europa.eu/en/healthtopics/vectors/VectorNet/Pages/VectorNet.aspx>.
3. Modelling Module in development for the VECMAP system. Produced by: Avia-GIS Zoersel Belgium; ERGO Ltd. Oxford, UK; MEDES, Toulouse, France for the European Space Agency.
4. **Jarvis, A, Reuter, H I, Nelson, A and Guevara, E** 2008 Hole-filled SRTM for the globe Version 4. Available from the CGIAR-CSI SRTM 90m Database (<http://srtm.csi.cgiar.org>).
5. **Hijmans, R J, Cameron, S E, Parra, J L, Jones, P G and Jarvis, A** 2005 Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology*, 25: 1965–1978. DOI: <https://doi.org/10.1002/joc.1276>
6. **Corine Land Cover** 2006 Raster data: <http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-raster-1>.
7. **Arino, O, Ramos Perez, J, Julio, J, Kalogirou, V, Bontemps, S, Defourny, P and van Bogaert, E** 2012 Global Land Cover Map for 2009 (GlobCover 2009). © European Space Agency (ESA) & Université Catholique de Louvain (UCL). DOI: <http://dx.doi.org/10.1594/PANGAEA.787668>
8. **Rogers, D J** 2006 Models for vectors and vector-borne diseases. *Advances in Parasitology*, 62: 1–35. DOI: [https://doi.org/10.1016/S0065-308X\(05\)62001-5](https://doi.org/10.1016/S0065-308X(05)62001-5)
9. **Lindsey, J K** 2007 Applying Generalized Linear Models. Springer, New York.
10. **Breiman, L** 2001 Random Forests. *Machine Learning*, 45: 5–32. DOI: <https://doi.org/10.1023/A:1010933404324>
11. **Scharlemann, J P W, Benz, D, Hay, S I, Purse, B V, Tatem, A J, Wint, G R W and Rogers, D J** 2008 Global data for ecology and epidemiology: a novel algorithm for temporal Fourier processing MODIS data. *PLoS ONE*, 3(1): e1408. DOI: <http://dx.doi.org/10.1371/journal.pone.0001408>
12. **VMERGE Data Portal Website** Available from <http://www.vmergedata.com>.
13. **Center for International Earth Science Information Network (CIESIN)/Columbia University, International Food Policy Research Institute (IFPRI), The World Bank and Centro Internacional de Agricultura Tropical (CIAT)** 2011 Global Rural-Urban Mapping Project, Version 1 (GRUMPv1): Population Count Grid. Palisades, NY: NASA Socio-economic Data and Applications Center (SEDAC). Available from <http://sedac.ciesin.columbia.edu/data/set/grump-v1-population-count> (accessed 02/03/2016).
14. **Nelson, A** 2008 Estimated travel time to the nearest city of 50,000 or more people in year 2000. Global Environment Monitoring Unit – Joint Research Centre of the European Commission, Ispra Italy. Available from <http://forobs.jrc.ec.europa.eu/products/gam/> (accessed 02/03/2016).
15. **EDENext Data Portal** Available from <http://www.edenextdata.com>.

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