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CONTENTS

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INTERPRETATIONS OF COMPLICATED FOLDED STRUCTURES AT THE LOWER PARTS OF ANTARCTIC AND GREENLAND ICE SHEETS

ABSTRACT. Complicated folded structures were recently recorded by radar survey in the lower portions of the Antarctic and Greenland ice sheets. From a geological point of view the Antarctic and Greenland ice sheets are considered as geological features, while the ice is classified as sedimentary or metamorphic rock. In this regard the genesis of the ice sheets is analyzed from the perspective of geodynamics and metamorphism, and complicated folded structures on radar profiles are interpreted as tectonic and metamorphic structures. This study considers the processes of three kinds of tectonic structures: glacial diapirs, glacial diapir folds and glacial intrusions. Radar profiles not only capture ice flow structure but can also detect the thermobaric field in ice sheet, and in this case the complicated folded structures are interpreted as representative of recorded metastable boundaries of ice recrystallization.

KEY WORDS: evolution and dynamics of ice sheets; analogies of the glaciological, geological and atmospheric objects

INTRODUCTION

Recently the complicated folded structures were recorded at the lower part of the Antarctic and Greenland ice sheets within the frame of BEDMAP, ABRIS, RADARSAT, GAMBIT/AGAP and other projects. These structures are expanded in the bottom of the ice sheet (of 1/3 to 1/4 of total thickness) and have a complicated, irregular shape that cannot be explained by the isochronal genesis of ice sedimentary accumulation [Cavitte et al., 2013; Fujita et al., 1999; Popov et al., 2007]. Formation of such structures also cannot be explained by generally accepted ice flow laws [Budd, 1969; Cuffey and Paterson, 2010].

Bell [Bell et al., 2011] explained the formation of complicated folded structures as a process of freezing-on ice at the base of the ice sheet. According to this theory, water at the bottom of ice-filled valleys refreezes to the base of the ice sheet because of the water's close proximity to the overlying ice and fluid flow into the above ice matrix. Instead of melting the ice around it, the convective thermal transfer of energy, produced by the activity of water, results in water freezing and buoying up the ice sheet. This leads to bending and modifying of the layers to the point of top layer erosion. However, based on this theory impossible to explain when and why the accretion ice disappears beyond the area of its formation, and its long duration expansion over the whole ice sheet is not observed subsequently. Moreover, in the radar profile aqueous layers were not registered, ie there is no source of ice accretion.

NEEM community members suggest [NEEM, 2013] that folded structures appeared due

to different rheological properties of ice near the base and overlying ice. Very large differences in ice rheological properties are documented between glacial ice (with crystal sizes of 1.5 mm and a strong preferred vertical c-axis orientation) and interglacial ice (with crystal sizes of 25 mm and multiple maxima fabrics). The viscosities of these two types of ice differ by a factor of 50–100, allowing glacial ice to deform very easily while the interglacial ice remains more rigid.

This paper displays alternative different visual logical interpretations on the origins of complicated folded structures as recorded on radar profiles of the Antarctic and Greenland ice sheets.

ICE SHEETS AS GEOLOGICAL OBJECTS

Antarctic and Greenland Ice sheets can be considered as geological formations when viewed in terms of continental changes and time scales, where ice is analogous to sedimentary and metamorphic rocks. From this standpoint, we can analyze the genesis of the ice sheets in terms of geodynamics whereby complicated folded ice sheet features, as captured in radar profiles, can be interpreted as glacial tectonic and metamorphic structures.

Ice has a natural tendency to operate like a plastic substance. Rocks also exhibit plastic properties. Applying analogies between the processes of ice flow in the Antarctic and Greenland ice sheets and tectonic processes in the metamorphic rocks of the lower Earth crust may offer additional or relevant clues in further interpreting the formation and processes of complicated shape structures within the ice sheet.

Analogies with the processes of geodynamics in other rocks that exhibit low viscosity and are capable of undergoing plastic deformation and flowing are also possible. These are salts [Alsop et al., 1996], anhydrite, gypsum, coals, and aqueous clays. Additionally, radar profiles may offer opportunities to detect the thermobaric field, and in that instance – complicated folded structures can be interpreted as the images of ice recrystallization boundaries.

GLACIAL DIAPIRS INTERPRPETATION

Diapirs structures

The occurrence mode of the complicated folded ice structures can be characterized as follows:

- They occur at the boundary of ice sheets with the bed and expand to heights of 1/3 to 1/4 of total ice sheet thickness;
- Pressure levels are some of the highest found in natural conditions of the ice on the Earth;
- Temperature is close to pressure melting point;
- Metamorphic intensity can reach the highest levels found in the natural conditions of ice on Earth. Similar conditions exist in the rocks with high metamorphic intensity (e.g. granulites);
- They occur in the lower Earth crust at the boundary with the upper mantle;
- Pressure is the highest one for the crust rocks under the natural conditions on the Earth;
- Temperature is the limit one for a solid phase of the Earth crust rocks close to melting temperature and the phase transformation to liquid mantle state;
- Metamorphic intensity is the highest one for the Earth crust rocks under the natural conditions on the Earth.

The diapir, similar to a granulite, is one of the typical geological structures in plastic rocks. It is a type of intrusion in which a more mobile and deformable material is forced into brittle overlying rocks [Serpukhov et al., 1976]. The diapir structures in the rocks

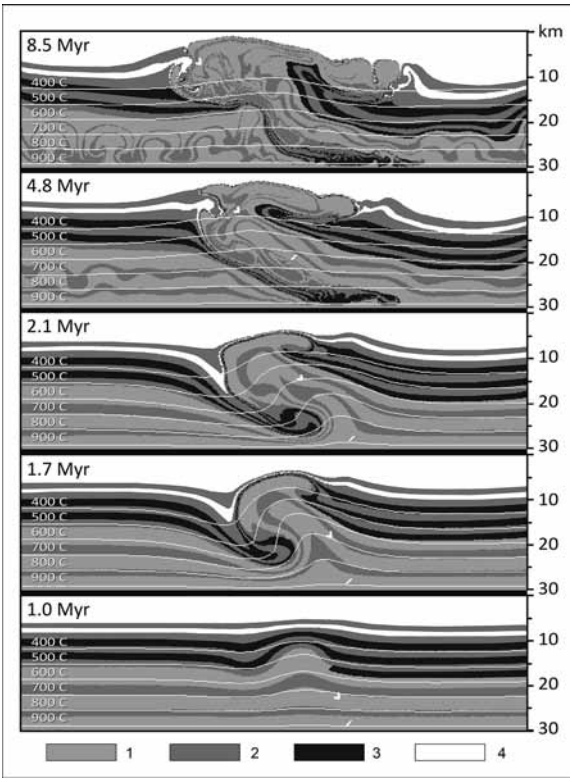


Fig. 1. Computational simulation of granulite diapir formation in the lower Earth crust:

1 – granulites; 2 – metabasalts; 3 – metasomatites; 4 – sedimentary rocks. The left-hand and right-hand scales are for temperature and depth in the Earth crust, accordingly [Gerya et al., 2000]

have been thoroughly studied under the natural conditions, and the processes of their formation have been simulated computationally (Fig. 1).

In accordance with morphological geotectonic geology [Khain and Lomize, 1995; Chorley et al., 1984; Scheidegger, 2004] the complicated structures in the lower part of the Antarctic and Greenland ice sheets may be identified as "glacial diapirs". This classification explains not only the shape, but also the genesis of these structures.

Glacial diapirs in the Antarctic ice sheet

A complicated folded ice structure, measuring ~15 km wide and ~600 m high, and surveyed using radar over Gamburtsev Subglacial Mountains in the East Antarctic region [Bell et al., 2011], was selected below as the first example of a glacial diapir (Fig. 2).

Generally in this region ice is flowing from area of Dome A. At that point the highest plastic deformations occur in the lower ice sheet layer [Budd, 1969; Cuffey and Paterson, 2010; Zotikov, 1963]. As appears evident in the bedrock topography, the lower layer flows within local combe and is overlapped by the less plastic ice sheet layer. The ice flow runs into a subglacial mountain ridge with a relatively high surface slope of about 15 degrees. This obstacle builds up excess pressure in the ice flow, forming the diapir core. The lower, most plastic ice is squeezed up from the high pressure area in front of the mountain slope to the area with less pressure above mountain peaks where thickness of the overlying ice is less. As may be supposed, this diapir core could break through to the surface, but it is protected by an overlying ice layer, with less plasticity. Moreover, in ice sheet the flow of the overlying layer entrains glacial diapir in further overcoming of the mountain ridge and flowing behind it.

Glacial diapirs in the Greenland ice sheet

Similar complicated folded ice structures were found in Greenland, and features identified in the region of the North Greenland Eemian Ice Drilling [NEEM] base are selected as an example (Fig. 3). From the perspective of structural geology, these structures correspond not to a stand-alone glacial diapir but to a system of glacial diapir folds. These are anticlinal, dome shaped folds, characterized by a heavily folded core which consists of older high plasticity ice. The diapir core is bounded by more gently dipping layers of the fold flanks.

The genesis of these glacial structures may be identical to diapir folds given how similar they are to the sedimentary cover of the Earth's crust. Such anticlinal structures

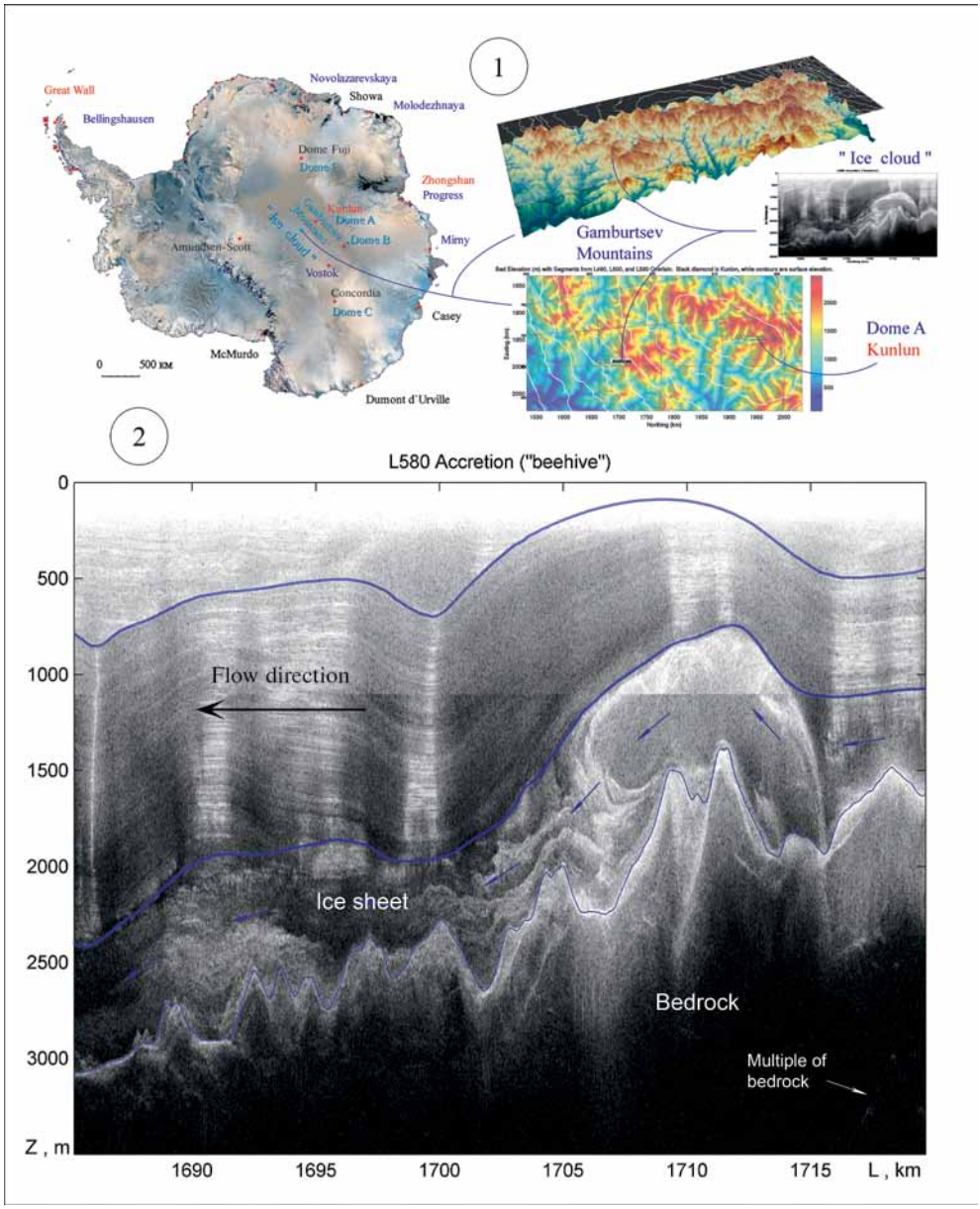


Fig. 2. Complicated folded structure in the region of Gamburtsev Subglacial Mountains, East Antarctica:

1. Location; 2. Radar profile: the lines mark boundaries between main flow layers
[Profile provided by M. Wolovick, Lamont-Doherty Earth Observatory, Columbia University, USA]

originate in the layered formations during intrusion of low-viscous rocks (e.g. in salts, anhydrites, gypsum, coals, and aqueous clays), which are able to deform plastically and to flow towards lower pressure areas.

The glacial diapir folds in the Greenland ice sheet do not coincide with the bedrock topography as it has been recorded for similar structures in the Antarctic ice sheet. They occur on the flat-bottom land which has slight slope of 3–5 degrees and cannot be considered as barrier, which initiates formation of the diapir core. The reason for the diapir folds formation in the Greenland ice sheets may be as a result of the squeezing-

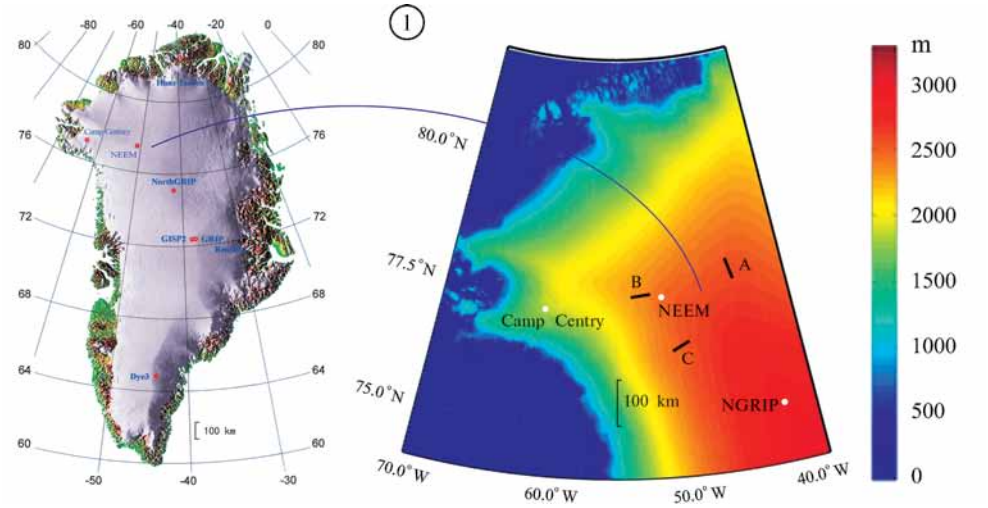


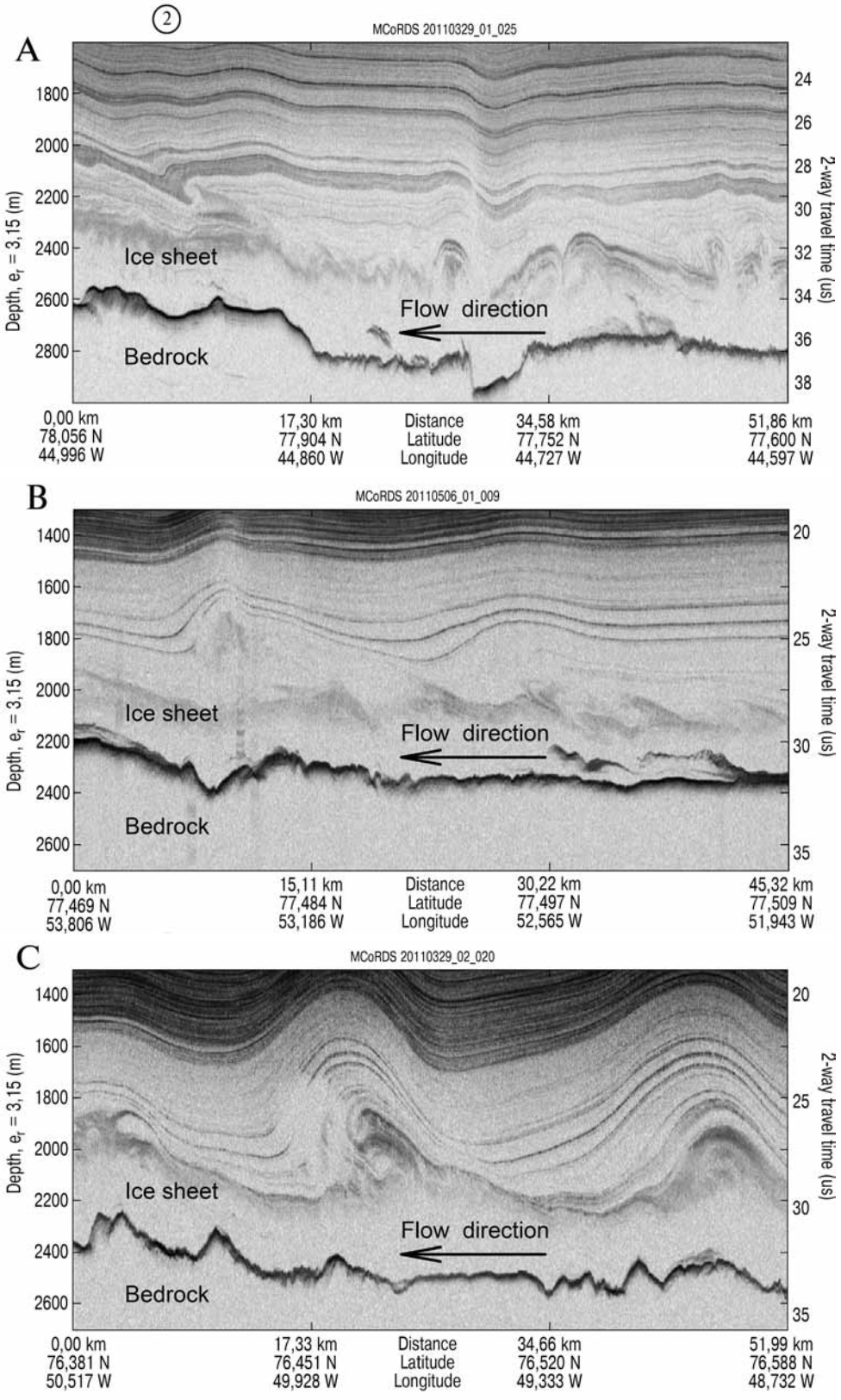
Fig. 3. Complicated folded structure in North Greenland in the region of NEEM base:
1. Location; 2. Radar profiles (see next page) [ftp://data.cresis.ku.edu/data/rds/]

up of the more plastic lower ice mass due to the vertical pressure gradient. In that case the intrusion of diapirs takes place towards the overlying formation with low pressure which can be caused not only by the thinner ice sheet areas but also by tectonic deformations and structural failures. Such areas may coincide with deflections downward into the local basins, which are seen in Fig. 3, as well as with areas of alternating forms of subglacial topography. The glacial diapir folds in the Greenland ice sheet are approximately the same sizes as glacial diapirs in the Antarctic ice sheet, measuring ~25 km wide and ~200–300 m high.

Thus, the complicated folded structures at the lower parts of Antarctic and Greenland ice sheets may be interpreted as diapirs or diapir folds, which are formed by the squeezing-up of the most plastic ice from the lower layer to the upper one. The squeezing-up process can be caused either by ice running into obstacles like subglacial mountain ridges or by the action of vertical pressure gradients in the overlying glacial mass. Regions of complicated folded structures are associated with ice sheet weakness in areas of ice thinning, local mounds, basins and alternating sign variations of subglacial topography.

INTERPRETATION OF GLACIAL INTRUSIONS

From a geotectonic aspect the complicated folded structures at the lower parts of the Antarctic and Greenland ice sheets can be also interpreted as glacial plutonic intrusion. The process of their formation is similar to the intrusion of molten magma (as a water analogue) to the Earth crust (as an ice sheet analogue). It is generally recognized that vast networks of lakes, rivers, and streams exist thousands of meters beneath the Antarctic and Greenland ice sheets [Box and Ski, 2007; Wright and Siegert, 2011; Wolovick et al., 2013 and others]. Under high pressure the subglacial water can cause hydraulic fracturing at the base of ice sheet bed. The phenomenon of hydraulic fracturing in ice was observed in a deep, overpressure borehole at Vostok Station, East Antarctica; Kudryashov et al., 2002. Lavryushin (1976) was supposedly the first to describe the mechanism of squeezing subglacial substrate into the cracks of the weakened zones at the lower glacier layers. He called such bodies "glacial dikes". Subglacial water layers may be a source of intruded ice, not over localized areas but over vast areas similar to the Earth's crust plutonic intrusions where the upper mantle is a source of magma invasion.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A
MCoRDS 20110329_01_025
Depth, e_r = 3,15 (m)
2-way travel time (us)
Ice sheet
Flow direction
Bedrock
0,00 km
78,056 N
44,996 W
17,30 km
77,904 N
44,860 W
Distance
Latitude
Longitude
34,58 km
77,752 N
44,727 W
51,86 km
77,600 N
44,597 W
B
MCoRDS 20110506_01_009
Depth, e_r = 3,15 (m)
2-way travel time (us)
Ice sheet
Flow direction
Bedrock
0,00 km
77,469 N
53,806 W
15,11 km
77,484 N
53,186 W
Distance
Latitude
Longitude
30,22 km
77,497 N
52,565 W
45,32 km
77,509 N
51,943 W
C
MCoRDS 20110329_02_020
Depth, e_r = 3,15 (m)
2-way travel time (us)
Ice sheet
Flow direction
Bedrock
0,00 km
76,381 N
50,517 W
17,33 km
76,451 N
49,928 W
Distance
Latitude
Longitude
34,66 km
76,520 N
49,333 W
51,99 km
76,588 N
48,732 W

METAMORHIC INTERPRETATION

Theory and experiments have shown that metamorphic transformations in the ice sheet lead to ice structure changes, and anisotropy, orientation of c-axes of crystals, and the influence of crystals size on relative dielectric permeability of the ice [Fujita, 1993, 2000; Matcheret, 2006]. If these changes have a high gradient, then they may be recorded as boundaries of radar signal reflections [Matsuoka et al., 2003]. Therefore, the radar profiles of the Antarctic and the Greenland ice sheets may display the structures of metamorphic ice transformations, and their interpretation can be made by analogy with the geologic structures and levels of metamorphic intensity.

The following types of metamorphism that may occur in the ice sheets and factors predetermining them (in brackets) were well known in rocks [Afanas'yeva et al., 2001; Bucher, 2011]:

- Pressure metamorphism (increasing of geostatic pressure);
- Thermal metamorphism (rise of temperature);
- Hydration metamorphism (interaction of rocks with water solutions);
- Dynamic metamorphism (tectonic deformations).

In addition, the rock metamorphism is subdivided to low, average and high intensity. Analogous to rock metamorphism, the complicated folded structures at the lower parts of the Antarctic and Greenland ice sheets can be interpreted as follows in the next sections.

Pressure and thermal metamorphism

From a metamorphic point of view, structure changes inside nontrivial bodies in the lower part of the ice sheets should be much higher than in surrounding ice, and these features may be interpreted as "relict ice domes" – ancient ice caps, which have undergone high intensity metamorphic changes – similar to the ancient platforms of the Earth's crust and overlapped by younger ice accumulations.

Local thermal metamorphism

Local geological processes in the Earth crust, such as hydrothermal vents, fumaroles, deep fault zones, as well as frictional heating of ice sheet are sources of intensive local thermal fields [Pattyn, 2010] that can produce thermal metamorphism in the lower part of the ice sheets.

Hydration metamorphism

Ice temperature at the lower part of the ice sheets is close to the pressure melting point, and therefore the hydration metamorphism can take place at the boundary with subglacial water. In light of this, the complicated folded structures on radar profiles may be interpreted as structures of intrusion and interaction of subglacial water and ice. This process is different from freeze-on of ice from subglacial water. In case of hydration metamorphism the structures may have complicated "nonlaminated" shapes that are common in fluid mechanics at the boundary of a nonlaminated flow (moving ice sheet) with a stationary medium (bedrock).

Dynamic metamorphism

The pressure-temperature changes of ice flow may cause dynamic metamorphism, and folded structures on radar profiles can be interpreted not only as the structures of ice flow but also as the distribution of "nontrivial" thermobaric fields, initiated by interaction of ice flow with bedrock.

Migration of the moisture saturated air layers over dominant obstacles may be considered as a similar process but not the geological one (Fig. 4 A, B). In this example, the cloud hanging around the obstacle represents the visual image of thermobaric field distribution of air flow.

By analogy, the structures on radar profiles of the ice sheets (Fig. 4 C) may be not an image

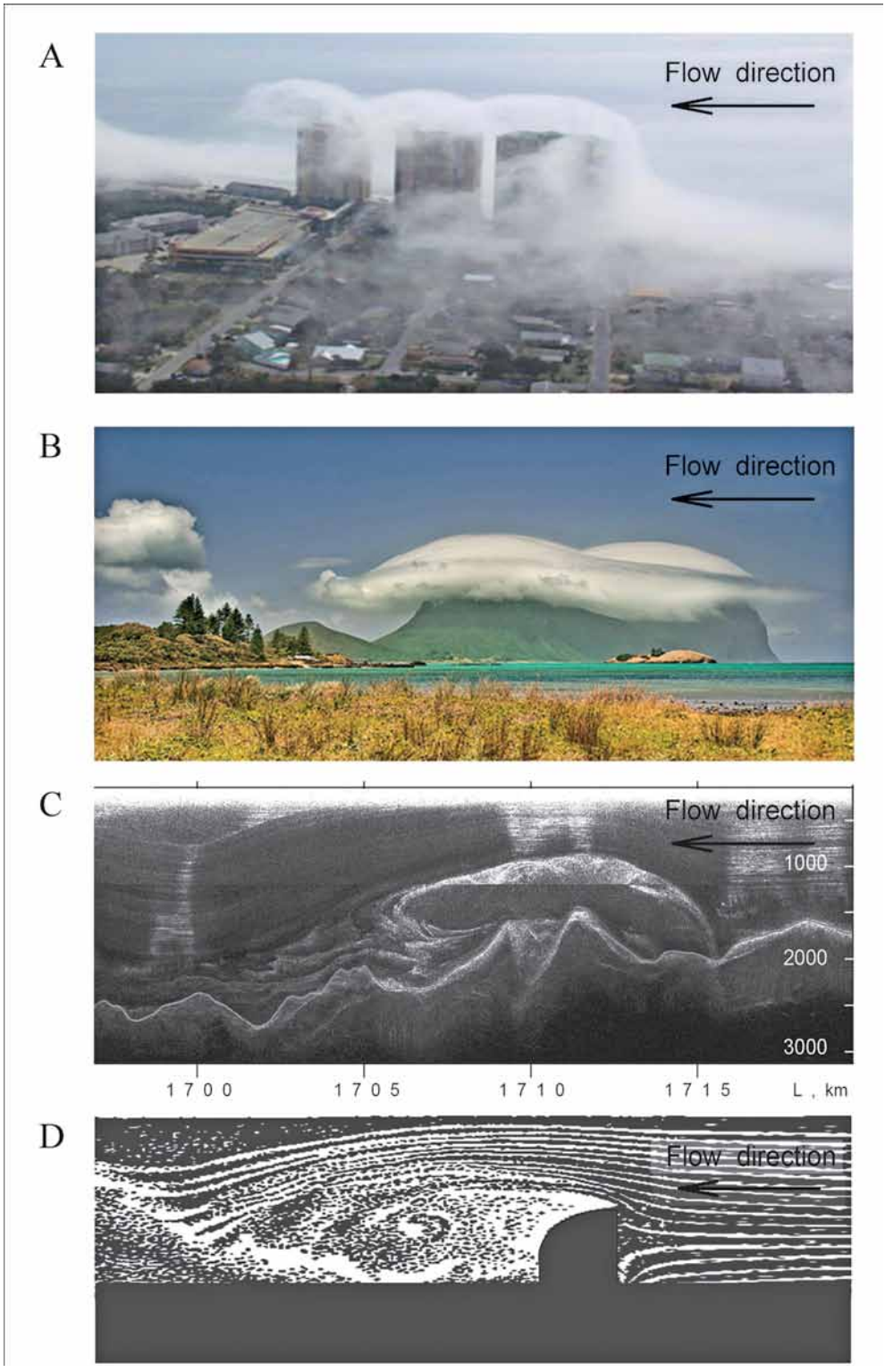

Fig. 4. Images of thermobaric field distribution in substance flow over barrier:

A, B – Metastable cloud structures over dominant obstacle; C – Nontrivial structure on radar profile in the region of Gamburtsev Subglacial Mountains, Antarctica; D – Typical flow structure of gas or liquid over barrier

of ice volume but the image of recorded metastable boundaries of ice recrystallization. No matter how paradoxical it looks it appears feasible that the thermobaric filed distribution associated with ice recrystallization may have a nonlaminated shape close to the flow structure of gas or liquid over barrier (Fig. 4 D).

CONCLUSIONS

If the Antarctic and Greenland ice sheets are considered as the geological objects and ice as the rock, then the complicated folded structures reordered on radar profiles may be interpreted as results of tectonic and metamorphic processes of different types similar to processes in the Earth crust. According with the tectonic analogies complicated folded structures at the lower parts of the Antarctic and the Greenland ice sheets may be interpreted as glacial diapirs, glacial diapir folds and glacial intrusions. The other probable reason of the forming of nontrivial structures is metamorphic changes in the certain areas of ice sheets under the action of geostatic pressure, temperature and subglacial water. Radar profiles may also detect thermobaric fields, and in this case the complicated folded structures can be interpreted as the images of recorded metastable boundaries of ice recrystallization. The real situation at the lower part of ice sheets can be investigated only by in situ sampling using core drilling methods with the following comprehensive analysis of the ice structure and composition. ■

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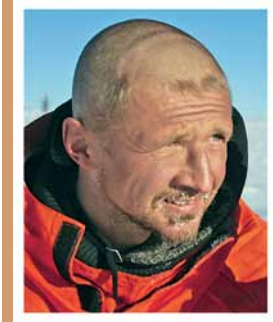

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SERBIAN AGRICULTURAL COMPETITIVENESS

ABSTRACT. Agricultural sector in Serbia is characterized by low competitiveness, as well as by domination of small agricultural husbandries of low productivity and production intensity. The authors of the paper, based on secondary sources, i.e. the analysis of numerous domestic and foreign documents in the field of agriculture, economic and rural development, provide state analysis of agricultural sector in Serbia, as well as a proposal of measures for improvement of this production and development of competitive and attractive rural regions.

KEY WORDS: agricultural sector, rural regions, competitiveness.

INTRODUCTION

The current extent and structure of agricultural production in Serbia, its high extensiveness, oscillatory, low productivity (resulted from multi-decade disinvestment), along with inefficient organization of production – circulations, represent basic factors which limit the competitiveness of domestic producers and exporters on the international market of agro-food products. Besides, numerous institutional-infrastructural obstructions and macro-economic instability (high macro-economic and total risk of the government, inefficient legislature and judiciary, under developed financial markets, under developed physical infrastructure, weak institutions), have a direct reflection to this economy field, too.

Development of rural areas substantially depends on agriculture development and greater investments in this production. Simultaneously, the greater investments in agricultural sector are caused by lower price of capital, i.e. by favourable macro-economic and business environment of the country, as well as a low non-commercial risk of the country. In that way, all assumptions of the competitiveness growth of domestic agriculture and rural areas remain dominantly on the macro-economic level.

In the paper, the authors will research the level of agricultural production competitiveness in Serbia and point out to further development directions of this production, of which will depend, to a large degree, upturn and development of rural areas and balanced regional development of the country.

ROLE OF AGRICULTURAL PRODUCTION IN THE NATIONAL ECONOMY OF THE REPUBLIC OF SERBIA

The sector of agriculture and rural development comprises agricultural production, forestry, fishery, food safety, animal welfare and rural development. This sector represents an important factor of the total national economy, from the aspect of share in gross value added, employment, and current account of the balance of payments. This situation is a product of two basic factors [National priorities for the international assistance for the period 2014–2017, with projections up to 2020, p. 222]:

a) Slow rate of restructuring in other sectors, which lead to weak investment activities

and consequentially poor opportunities for employment in the sectors beyond agriculture,

b) Availability of rich natural resources for agricultural production in the Republic of Serbia.

The following data lead to significance of agricultural and rural sector for the national economy.

I. The share of activity "*Agriculture, forestry and fishery*", in gross added value of the Republic of Serbia in 2011 was amounted 10.5%, and, together with production of food products, beverages and tobacco, the agro-food sector makes 16.0% of gross added value of all activities in the Republic of Serbia [Statistical Yearbook of the Republic of Serbia, 2013, pp. 130, 132]. According to data of the World Bank, the agriculture in Serbia participates with 9% in gross domestic product (2011), which is significantly higher than in regard to developed European countries (Table 1).

II. According to data of the World Bank (Table 1), Serbia has been characterized by high employment in the activity sector "*Agriculture, forestry and fishery*", especially in regard to high-developed European countries (Table 1). According to data of the Labour Survey of the Statistical Office of the Republic of Serbia [Bulletin 578, 2014, p. 56] in 2013, in employees structure in the Republic of Serbia, in the activity sector "*Agriculture, forestry and fishery*" was employed 21.3% employees, and in rural areas even 43.9%. Informal employment in the Republic of Serbia in the year 2013 was amounted 19.3% (in rural areas 34.5%), and in the activity sector "*Agriculture, forestry and fishery*" in rural areas, the informal employment was achieved up to 64.4% [the Labour Survey, 2013, Bulletin 578, pp. 59–60].

III. Serbia has been realizing a positive trend in foreign trade exchange of agro-food products with the world. The export of agro-food products (group "Food and live animals") was increased from 924 million USD in 2005

Table 1. Share of agriculture in gross domestic product (GDP) and employment in agriculture in selected European countries

Countries	Agriculture/ value added, % of GDP, 2011[1]	Employment in agriculture, % of the total employment, 2012[2]
High-developed economies		
Austria	1.5	4.9
Belgium	0.7	1.2
Czech Republic	2.3	3.1
Denmark	1.2	2.6
France	1.8	2.9
Germany	0.9	1.5
Italy	1.9	3.7
The Netherlands	2.0	2.5
Norway	1.6	2.2
Portugal	2.4	10.5
Slovakia	3.9	3.2
Slovenia	2.5	8.3
Spain	2.7	4.4
Sweden	1.8	2.0
Great Britain	0.7	1.2
Central and East Europe countries		
Albania	18.6	42.0
Bosnia & Herzegovina	8.7	20.5
Bulgaria	5.6	6.4
Croatia	5.1	13.7
Hungary	3.5	5.2
Poland	3.5	12.6
Romania	7.4	29.0
Serbia	**9.0**	**21.0**
Ex-USSR countries		
Armenia	20.7	38.9
Azerbaijan	5.8	37.7
Byelorussia	9.9	–
Georgia	9.3	–
Russian Federation	4.3	–
Ukraine	9.6	17.2

Source: The World Bank, http://data.worldbank.org/indicator/NV.AGR.TOTL.ZS, http://data.worldbank.org/indicator/SL.AGR.EMPL.ZS/countries?display=default, access date 3rd May 2014.

[1] Agriculture encircles crop and livestock production, forestry, hunting and fishery. For high-developed countries, Poland and Hungary the data refer to the year 2010, and for France the data is for the year 2009.
[2] Data for employment: Albania (2010), Armenia (2011), the Netherlands (2011).

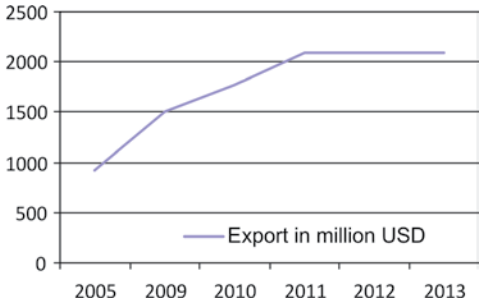

Fig. 1. Export of "Food and live animals" from Serbia in the period 2005–2013.

Source: Calculation of the authors according to data of the SORS for the corresponding years.

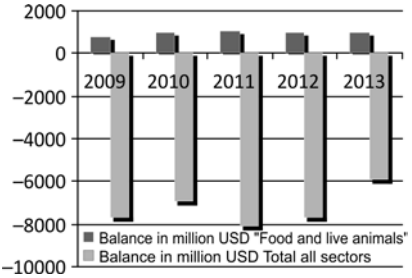

Fig. 2. Balance of foreign trade exchange in export of "Food and live animals" and all sectors, in the period 2009–2013.

Source: Calculation of the authors according to the SORS data.

to 2.1 milliards USD in 2013, i.e. for 127% (Fig. 1). Besides, Serbia provides market surpluses of many agricultural products which are export-oriented (fruits, cereals, sugar), and agro-food sector of Serbia has been, in years, the only sector in the national economy with surplus in foreign trade exchange (Fig. 2). The surplus in foreign trade exchange of agro-food products, in the period 2005–2013, had ranged from 150 million USD (2005) to 949 million USD (2013).

IV. Rural areas of Serbia occupy 85% of Serbian territory, 55% of population live in them and they form 41% of the country's GDP [Bogdanov, 2007, p. 31]. Although in agriculture of Serbia dominate, so called, small and medium agricultural husbandries (according to data of the Agricultural Census in 2012, even 77.4% of the total number of agricultural husbandries in Serbia, with utilised agricultural area, have property to 5 hectares), these husbandries have great significance on the local commodity market from food production point of view (self-sufficiency rate and food safety), as well as from the resources preservation and rural environment point of view [see Draft Strategy of Agriculture and Rural Development of Serbia in the period 2014–2024, p. 55].

V. The Republic of Serbia has favourable factorial conditions (good geographic location of the country, high diversity of rural areas, high-quality and unpolluted agricultural land, water resources) for development of intensive agriculture, as well as liberalized agricultural products trade with many countries: surrounding countries (CEFTA Agreement), possibility of preferential export for strategic products in the EU, USA, Russian Federation etc. More on the trade agreement and foreign trade agreements can be seen at the internet SIEPA presentation [http://siepa.gov.rs/sr/index/sporazumi, date of access 5th April 2014].

EVALUATION OF AGRICULTURAL COMPETITIVENESS IN THE REPUBLIC OF SERBIA

Besides all mentioned in the previous item, the competitiveness of agricultural sector on domestic and international market has been extremely high [see Paraušić et al., 2013, pp. 158–171; Paraušić, Cvijanović, 2014]. In accordance to research of the group of authors, the only competitive advantage of rural areas in the countries of West Balkan, to which belongs also the Republic of Serbia, are [Stantič, 2011, p. 2]: (1) low labour price and (2) high quality natural resources.

The most important indicators of Serbian agricultural sector non-competitiveness are given below.

I. *Low export value of agricultural products per a hectare of utilised agricultural area* in regard to the EU countries (Table 2, Fig. 3).

Low export results are the result of unfavourable export structure, low export

Table 2. Export of agricultural products from Serbia and selected EU countries, 2012.

	UAA[1], 2010	Export of agro products in the total export of commodities, %	Export of agricultural products in 000 US$	Export of agricultural products per ha of UAA in 000 US$
The Netherlands	1,872.350	15.7	102,944.900	54,982
Austria	2,878.170	9.5	15,811.705	5,494
Italy	12,856.050	8.5	42,561.115	3,311
France	27,837.290	13.8	78,510.960	2,820
Spain	23,752.690	16.8	49,381.752	2,079
Greece	3,477.900	19.4	6,882.926	1,979
Serbia	3,437.423	25.0	2,838.250	826

[1] UAA – The utilised agricultural area (UAA) describes the area used for farming. It includes the land categories: arable land; permanent grassland; permanent crops, and other agricultural land such as kitchen gardens (even if they only represent small share of the total UAA). The term does not include unused agricultural land, woodland and land occupied by buildings, farmyards, tracks, ponds, and so on. For Serbia data for 2012. In Greece common land is excluded.

Source: For UAA data of the Eurostat, http://epp.eurostat.ec.europa.eu, access date 10th May 2014. For agricultural products data of the WTO statistics database for 2012, http://stat.wto.org/Home/WSDBHome.aspx?Language=, access date 10th March 2014.

unit value, impossibility of realizing price competitiveness on the foreign market, impossibility of providing sufficient amounts of commodity for export, as well as providing continuity in supply of the international market with products of homogenous quality. Especially, a great problem is unfavourable export structure of agro-food products. Serbia has a small number of products in the sector "Food and Live Animals" in which exchange it makes a high surplus. Those are, primarily, stock market products: cereals (especially maize), berries (dominantly frozen raspberry and sour cherry), refined sugar, and the prices of those products are determined by the world food market, where the price is the only basis for applying. The unfavourable export structure (domination of primary products, small share of manufacturing articles, especially those based on meat and milk), causes a low unit and total value of food export. The presented data (Table 2, Fig. 3) point out to the fact that deficiency or inappropriate quality of agricultural area is not a limiting factor for high competitiveness in the agricultural sector (the example of the Netherlands), and vice versa, that the favourable factorial conditions in the field of agriculture must not "lead" to high export results and high competitiveness of agriculture (the example of Serbia).

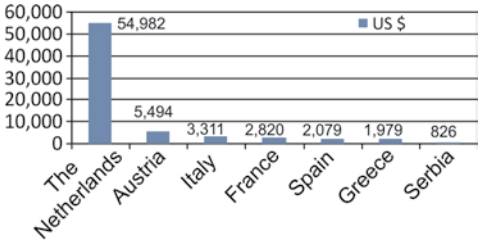

Fig. 3. Export of agricultural products per ha of UAA, in 2012, in selected European countries and Serbia.

Source: Calculation of the authors according to the data in Table 2.

II. *Extensiveness (low productivity) of agriculture* is a result of low support from the agrarian budget and under developed and unfavourable financial market for higher investments in modernization and consolidation of agricultural. The agricultural investments are of the essential significance for promoting the agricultural growth, poverty reduction and preservation of the environment [The State of food and agriculture, 2012], and their deficiency

leads to an extensive agriculture, highly dependable of climatic factors. In accordance to data on productivity in agriculture for the selected countries, which are presented through indicators "Agriculture, added value per an employee" (Table 3), can be seen that productivity in the Republic of Serbia, in the field of agriculture, is far lower in regard to high-developed European countries, as well as that lower productivity than Serbia, in agriculture, have the following countries: Albania, Azerbaijan and Georgia.

For data on livestock breeding share in the total agricultural production value: FAO Statistics, http://faostat.fao.org, access date 15th May 2014.

III. ***Low share of livestock production in value of the total agricultural production.*** The livestock breeding has great significance and multiple roles in valorisation of working and production potentials in agriculture of every country. The share of livestock breeding in value of the total agricultural production in the Republic of Serbia amounts 34.2% for the year 2011 (FAO data, Table 3) and this is significantly lower share in regard to the selected high-developed countries. The livestock production of Serbia is characterized by numerous financial, organizational-market problems, as well as deficiency of set and efficient market connections between the primary agricultural producers, forestallers, exporters and meat processors, owing to which this production records a permanent decline [see more Paraušić et al., 2010].

CONSEQUENCES OF AGRICULTURAL NON-COMPETITIVENESS OF THE REPUBLIC OF SERBIA

Deficiency of Serbian agricultural competitiveness has a series of negative implications on economic and regional development of the Republic of Serbia, and the most important are as follows:

I. ***Lack of long-term and stable growth of agricultural production.*** According to the SORS data [Statistical Yearbook, 2011, 2013] in 2008,

Table 3. Productivity in agriculture and share of livestock breeding in value of the total agricultural production

	Agriculture, value added per employee, permanent prices 2005 US$, 2012[1]	Share of livestock breeding in value of the total agricultural production in %, 2011[2]
High-developed economies		
Austria	33,213	58.4
Belgium	56,515	55.8
Czech Republic	6,680	53.4
Denmark	31,885	71.8
France	75,178	44.9
Germany	31,641	62.6
Italy	43,151	35.2
The Netherlands	60,398	66.6
Norway	65,249	76.5
Portugal	8,906	43.9
Slovakia	12,735	45.2
Slovenia	112,484	62.2
Spain	33,681	35.6
Sweden	38,006	67.4
Great Britain	28,466	59.8
Central and East Europe countries		
Albania	3,630	51.7
Bosnia & Herzegovina	28,183	38.1
Bulgaria	16,101	36.2
Croatia	23,521	37.5
Hungary	9,964	43.1
Poland	4,111	57.2
Romania	9,117	33.9
Serbia	3,904	34.2
Ex-USSR countries		
Armenia	8,389	41.5
Azerbaijan	1,085	42.7
Byelorussia	7,845	49.8
Georgia	2,512	45.4
Russian Federation	5,969	50.0
Ukraine	4,375	31.4

[1] Agriculture includes value added of forestry, hunting, fishery, as well as of crop and livestock production. For the Slovakian Republic (2010); Slovenia (2010); Hungary (2010); Poland (2010); Serbia (2009).
[2] Gross production value, permanent prices 2004–2006 in million USD.

Source: For data on productivity (Agriculture, value added per an employee): The World Bank, http://data.worldbank.org/indicator/EA.PRD.AGRI.KD/countries?display=default, access date 10th May 2014.

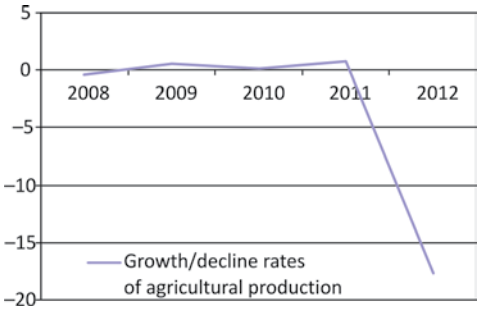

Fig. 4. Growth/decline rates of agricultural production in the Republic of Serbia in the period 2008–2012.

Source: SORS, Statistical Yearbook 2011, Statistical Yearbook 2013.

agricultural production has not recorded some significant increase (base index 2005 = 100), and in the year 2012 was decreased for almost 17.7% (see Fig. 4).

II. ***Regional diversities and rural poverty.*** Although in gross domestic product of rural areas, a dominant share has the activity "Agriculture, Forestry and Fishery" (the share of agriculture in GDP of rural areas amounts around 30%), realized gross domestic product per capita in these areas (data for the year 2004), has been lower for one forth from the national average of the republic [the National Program of Rural Development of the Republic of Serbia 2011–2013, p. 9].

Professor Bogdanov [2007] points out that economic structure of Serbian rural areas has been highly dependent from the primary sector (dominate agriculture, food industry, mining and energy), and still have been based on depletion of natural resources; dominates the traditional, mono-functional and low productive agriculture, while the rural population represents the poorest socio-economic category in the Republic of Serbia.

The authors [Mijačić, Paunović, 2011, p. 379] point out to the expressed regional dissimilarities at all *Nomenclature of Territorial Units for Statistics (NTUS)* levels, which are among the greatest in Europe, as well as to data that, of 45 under developed municipalities in Serbia, those 30 had never changed their level of development in more than 4 decades, and even the regional disparities had been accelerated in the period 2001–2010.

According to the Opinion of the European Economic and Social Committee on Rural Development and Employment in the countries of West Balkan in 2011 [Stantič, 2011], some of developmental limitations of rural areas are: a) under developed physical infrastructure, b) under developed and remote infrastructure which provides social and health care services, education, culture, sports services, etc., c) under developed labour, capital, agricultural market, d) low level of entrepreneurship of rural population and local authorities.

The authors [Živkov, et al., 2012, pp. 10, 11] point out that Serbia is among the most rural countries in Europe, with unfavourable parameters for development of rural areas, especially regarding infrastructure, education, employment access point of view. According to those authors, in the future is possible to improve the condition in rural areas, only in a way it will realize overall economic development, which does not occur where the administration wants it to be seen, but where the economy wishes to invest. In accordance to the same source, the signals sent by agrarian, but also the whole economic policy in Serbia are so variable, unstable and erroneous, that even in case of their change, in the near future, these policies will not decisively affect to directing activities of population in rural areas.

Numerous studies in the field of rural development and life standard [Life Standard Study, 2008, pp. 146–147; Bogdanov, 2007; Cvejić et al., 2010, pp. 14, 61], point out to low productivity of agricultural production, first of all, due to its extensive character, which lead to low gains and low life standard of rural population.

III. ***Migrations and threatening of demographic structure of rural areas.*** In the period from 1991 to 2002, the population in rural areas of the Republic of Serbia had been

decreased for 3.6% in comparison with the total decline of 1% at the state level [National Program of Rural Development 2011–2013, pp. 11, 12]. According to the same source, it is especially migrations of young population (especially female population) towards bigger urban centres, which leads to an unequalized regional development and unfavourable age structure of population in rural areas.

RECOMMENDATIONS FOR STRENGTHENING THE COMPETITIVENESS OF AGRICULTURAL SECTOR AND RURAL REGIONS IN SERBIA

In order that small and medium agricultural husbandries in Serbia (which dominate in structure of the total husbandries) would improve their physical and economic performances (through ensuring the stable and high income sources on the husbandry) and become more competitive on domestic and foreign market, it is necessary that the agricultural producers engage more active on elimination of their numerous internal limitations in the fields of:

- Education, acquiring new knowledge and skills, better awareness, etc.
- Development of entrepreneurial and competitive spirit,
- Better apply of innovation in production and business, which are not and must not be always connected to great financial investments,
- Changes in consciousness and mentality in directions of a real recognition of: own mistakes and problems, significance of investments into products of higher-processing-phase, as well as the significance and importance of introduction of quality standards, improvement of products quality, etc.

Maybe the most important is raising the awareness of agricultural producers regarding necessity of over viewing own development in long-term, regarding that mostly, due to a short term interest, the agricultural producers neglect the general interests and established business agreements with a cooperative, association, etc.

Besides these activities which are in domain of the agricultural producers, it is important that husbandries get support of the political leaders, in form of a stimulating economic and agrarian policy, developed institutional capacities of the state, as well as developed physical, market, financial and innovation infrastructure in the country.

Below measures of agricultural husbandries strengthening will be discussed, which have been under the state's authority, i.e. the government of the Republic of Serbia, and in accordance to the legal [Law on agriculture and rural development, Official Gazette of the Republic of Serbia, No. 41/2009 and 10/2013 – the state law; Law on incentives in agriculture and rural development, Official Gazette of the Republic of Serbia, No. 10/2013] and strategic framework in the field of agriculture and rural development in Serbia and the EU in the period after the year 2014 [Draft of the Agricultural and Rural Development Strategy for the period 2014–2024; National priorities for the international support for the period 2014–2017, with projections till 2020; The CAP towards 2020: Meeting the food, natural resources and territorial challenges of the future, EC 2010; Regulation (EU) No 1305/2013].

According to Liefert and Swinnen [2002, p. 28] for improvement of agriculture and rural areas competitiveness in the field of transitional countries, the ***growth of productivity in agriculture*** is more significant factor than the agricultural production growth, because it only can lead to income increase in agricultural sector and the growth of rural population life standard. Taking it into consideration, aiming to make conditions for property consolidation and productivity growth (through modernization of husbandries, investments in technical-technological improvement of agricultural

production, processing and sale), it will be important the state's support in form of: a) predictable and stimulating agrarian policy and b) development of financial market for attracting the external funding sources: establishing the efficient credit mechanisms, adjusted to the specific and long-term needs for crediting the agricultural producers (adjustment of terms and conditions for credit disbursement), development of non-banking institutions, etc.

Market development: a) of agricultural products (efficient policy of competition protection in the field of "grey" economy and control of some companies dominant position misuse; development of commercial inscriptions market; terminal market; implementation of intervention repurchase in case of obvious "mistakes" of the market; development of cargo terminals and logistics centres; b) financial market (money and capital); c) land (change of policy in the field of land inheritance; land turnover; setting the efficient system of land management, etc.); d) knowledge (ensuring the efficient transfer of knowledge, information and innovations by the agricultural extension service to agricultural producers). More on the competition development on the agricultural market in Serbia can be seen in [Paraušić et al., 2010a].

Creating a stimulating business environment for greater investments in agricultural production and non-agricultural activities (through minimizing investment risk), for employment increase, development of cooperatives and the sector of small and medium enterprises and entrepreneurship (SMEs). Creating the stimulating business environment implies adjustment of: a) tax policy (reducing tax and non-fiscal charges); b) labour legislation, c) trade regulations and d) generally the measures of economic and agrarian policy. Anyhow, the attitudes of the Serbian Association of Employers [Terms and burdens in the Serbian economy, 2010; Attitudes of employers on business environment, 2013] point out constantly on numerous elements of unfavourable business environment, for the SMEE sector activities.

Improvement of rural population life quality and making favourable conditions for diversification of income and the rural population activities, which imply: a) improvement of physical and social infrastructure in the country, b) creating the stimulating business environment and c) making conditions for overall economic development (development of industrial production, service activities). Previously, it aimed to provide the favourable conditions for employing the rural population beyond agriculture (in context of income and activities diversification), which will be necessarily in the period to come, with increase of productivity and decrease of a number of needed employees in agriculture.

Building administrative capacities (in the Ministry of Agriculture and the Environment Protection of the Republic of Serbia and the Ministry of Finances of the RS) for using IPARD funds (pre-accession funds of the EU meant for rural development in the West Balkan countries), which is also stated in the EC Report on Serbian progress for the year 2013 in the field of Agriculture and Rural Development [EC Report on progress of Serbia for the year 2013]. Serbia has no opportunities to use the IPARD funds in the period 2013 + 3, in regard that it had no possibility to fulfil the EC administrative requirements till 2013. In the document adopted by the Government of the Republic of Serbia in 2013 [National priorities for the international support for the period 2014–2017, with projections till 2020, p. 244] is stated that the IPARD operational structure and the IPARD measures are going to be defined and accredited in the year 2016, while in 2017 will be signed authorization transfer for the IPARD funds management. The group of authors [Živkov, et al., 2012] point out that in Serbia, neither is administration ready to adjust to the EU planning system and implementation of measures for rural development, nor the population is qualified to use the EU funds for rural development

(insufficiently developed local action groups, public-private partnership, insufficient information of the rural population, etc.).

Development of public institutions (establishment of the rule of law through the efficient legislative and juridical power) which ensures/provides: a) passing necessary laws and an efficient application of the laws, b) contracts compliance, the efficient protection of proprietary rights and an equal access of all participants to the resources, commodity market, financial market, c) building trust among agricultural producers/entrepreneurs, as well as the trust between civil society and economy and governmental authorities, institutions, agencies, etc. See more [Paraušić, et al., 2007].

CONCLUSIONS

Strengthening the domestic agricultural producers' competitiveness is a crucial issue of domestic agriculture. Of this is dependant a balanced regional development of the country, development of competitive and attractive rural regions, possibility of rural population employment, as well as staying of the rural population in the country and village survival.

The authors in the paper were analyzed agricultural production and rural regions in Serbia and were pointed out to numerous problems in this field, which have manifested though low productivity and competitiveness of domestic production, underused ability to export, underdevelopment and poverty of rural areas.

In order that small and medium agricultural husbandries, which dominate in agriculture of Serbia, should improve their physical and economic performances and become more competitive, it is necessary, maybe the most important, to engage more active the agricultural producers on removing their numerous internal limitations, which repose in mentality and under developed consciousness on future development. Besides, it is important that husbandries get support of political leaders, through implementation of numerous measures of support: a) insurance of predictable and stimulating agrarian and total economic policy, b) market development (agricultural products, capital, land), c) creating a stimulating business environment for greater investments, employment, overall economic development of the country and diversification of income and rural population activities.

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INDEXING OF MAPPING SCIENCE JOURNALS

ABSTRACT. Bibliometric analyses based on citations are most often at the forefront where scientific publications are concerned. A fact often neglected is that the visibility and availability of scientific publications are basic prerequisites for future reading, citation and influence. Journal visibility can be significantly improved by providing open access and availability through popular online databases. In this study, we investigated 112 mapping science journals to determine the visibility of scientific publications in a smaller interdisciplinary field. In addition to other data, we collected data on open access, indexing, subject areas within the *Web of Science* and *Scopus* bibliographic databases and the number of journals in these databases. The coverage of mapping science journals in 14 bibliographic databases was analyzed. Only 11% of the titles from the journals analyzed were indexed in 10 or more databases. *Google Scholar, Scopus, Bibliotheca Cartographica* and *GEOBASE* include most mapping science journals, while only 19 are included in *Web of Science*. A comparison indicates more thorough coverage of an individual journal in *Web of Science* than in *Scopus*. Only a few mapping science journals appear in the *Directory of Open Access Journals*, despite the large number of open access mapping science journals available. Adding subject categories within databases does not facilitate finding mapping science journals, which are dispersed among numerous, mostly inadequate categories in the *Web of Science* and *Scopus* databases.

KEYWORDS: indexing, mapping science, scientific publication, bibliographic database

INTRODUCTION

Scientific publishing, especially periodical publishing, has been extremely dynamic ever since it began. Journals are the most numerous representatives, varying in the characteristics such as frequency of publication, number of years of issue, editorial policy, types and number of published papers, scope of discipline, peer-review process and popularity. Efforts to estimate the number of currently active journals have been the subject of several published papers. The number of journals published increased slowly at first, and there were only 10 scientific journals being published in the mid 18th century [Hook, 1999]. De Solla Price estimated that 100,000 journals would be published between 1665 and 2000 [de Solla Price, 1961]. The central ISSN office in Paris registered 1,749,971 periodicals up to 2013, but it is difficult to ascertain how many of them are still active. Using *Ulrich's Periodical Directory* and applying Bradford's law to Thomson Reuters citation databases, Mabe estimated the total number of active reviewed journals at 15,000–16,000 [Mabe, 2003]. By applying similar methodology in their study [Björk, Roos, & Lauri, 2008], the authors arrived at the figures of 23,750 for

active peer-reviewed journals, and 1,350,000 papers published in 2006. Larsen and von Ins compared various research results with their own data collected from analyzing journal growth in various index publications, and estimated the number of active reviewed journals at 24,000. At the same time, they concluded journal growth varies significantly from one field to another and that there has been an increase in other communication channels for publishing papers, such as conference proceedings, open archives and personal websites [Larsen & von Ins, 2010]. The most popular journal register, the aforementioned *Ulrich's Periodical Directory,* currently includes more than 335,000 journals (published by more than 90,000 publishers), of which 28,135 were active, reviewed journals in August 2012 [Harnad, 2012].

The increase in the number of scientific journals has made it difficult for scientists to navigate all this information. By the mid 19th century, the volume of information published meant it was impossible to keep up with everything written [Jones, Huggett, & Kamalski, 2011]. This phenomenon spurred the development of index and abstract publications, which condensed information about the large number of published papers. In the past 60 years, computer technology has ensured the rapid development of these publications in digital form, and online databases available online have become an indispensable source of published papers. Nowadays, online databases vary in volume and the range of information provided (bibliographic, full text, citation), data type (text, numeric, multimedia, etc.), the content included (journals, conference proceedings, books, book chapters, dissertations, etc.), the subjects they cover (thematic, multidisciplinary), the extent of the content index (selective, cover-to-cover), and level of access (subscription, open access). The line between various types of index publications, which was clear in the printed age, is becoming increasingly blurred. Hyperlinks have enabled index publications to become a part of the global dynamic and viral information space.

Studies about information behavior are providing evidence of constant changes in the way scientists obtain the information they need [Bates, 2010], while bibliographic indexing and bibliographic databases are powerful tools that enable the organization of, and navigation through, the huge quantity of scientific research published [Jones et al., 2011]. Longitudinal studies of scientists' reading habits showed they depended exclusively on printed index and abstract publications in printed form, tables of contents (TOC) and other information systems in 1977. In contrast, in 2005, most scientists (93%) were using "electronic sources", 63% were referring to index and abstract publications in printed form and available online, while 14% were using web search engines such as Google, Yahoo, and others [Tenopir, King, Edwards, & Wu, 2009].

Some bibliographic databases, especially those with a long history, or maintained by prestigious institutions, enjoy a high reputation among the scientific community, so the selection criteria for including journals are generally accepted and taken to indicate the quality journals and published papers. Indexing in popular and reputable bibliographic and citation databases, and citation frequency, are currently important indicators of the visibility and impact of journals. The field of the earth sciences, including geodesy, and the field of geography, including cartography, has changed dramatically over the last two decades, and new disciplines have appeared, influenced by computer technology implementation, showing a high level of interdisciplinarity. "The goal of Modern Geodesy is nothing less than to monitor changes in a range of physical processes in the solid earth, the atmosphere, and the oceans in order to improve our understanding of this fragile, precious and stressed planet" [Rizos, 2011]. Because of the complexity of the emerging terminology in this area, for the purpose of this research, the term "mapping science" will be used, which includes surveying, geodesy, cartography, spatial data infrastructures, cadastre, photogrammetry and remote

sensing. In mapping science, journals are still the main channel of scientific communication, distributed across various, changing disciplines and often difficult to identify and read.

In an attempt to define the body of mapping, we selected one hundred active science journals publishing the majority of papers in this field. The publishers of selected mapping science journals are in about 30 countries, primarily Germany, the United States, and Poland. Half the journals are published in English, the official langue of scientific communication, while less than half are available in open access (OA), which ensures free access and the potential use of published research results [Frančula, Stojanovski & Lapaine, 2012]. The specific characteristics of mapping science journals provided the main motivation for continuing research in this topic, and the research questions in this paper included the following. What is the visibility of mapping science journals based on their indexing in the corresponding thematic, most consulted, multidisciplinary bibliographic databases? How do open access journals affect the visibility of the materials published? How are mapping science journals classified within multidisciplinary databases? Is mapping science journal classification aligned with journal scope, and does it contribute to journal visibility? According to our sources, no research papers have been published analyzing mapping science journals in such a comprehensive way.

RESEARCH SCOPE

Although more than two-thirds of searches conducted by search engines are done using Google [OCLC, 2010], where scientific publications are concerned, the main source of information is still bibliographic databases produced by various expert associations and commercial companies [Tenopir et al., 2009]. Most scientific publications are papers published in journals, and the criteria for their inclusion vary from one database to another. Most producers of bibliographic databases require basic editorial standards, such as timeliness, international editorial boards, international authors, and so on [Roales-Nieto & O'Neill, 2012], while some databases are concerned with relevance to the field, journal citations, the reputation of the members of the editorial board or authors, and so on. Some database producers include all the published papers in a selected journal ("cover-to-cover"), while others select papers or types of papers based on the discipline covered by the database, frequently limiting the selection to original scientific and review papers.

Inclusion in subject and multidisciplinary databases is certainly an important factor contributing to journal visibility, because researchers rarely visit only one journal's website. Depending on the discipline, researchers focus on databases that cover their particular areas of interest well, or multidisciplinary databases that include tens of thousands of journals by several thousands of publishers. All researchers aim to find the simplest, fastest way to get an overview of all papers published in their field, and typically want to be able to filter content according to a variety of criteria, most often qualitative. Furthermore, researchers consider the criteria applied by database producers in selecting journals ensure the quality of the content. Therefore, it is important for a journal to be included in as many subject and multidisciplinary databases as possible, in order to improve usage and increase visibility, along with potential citations and journal impact. When selecting a journal in which to publish their papers, researchers also consider the journal's reputation, especially regarding tenure and promotion decisions [Caron, Roche, Goyer, & Jaton, 2008]. In many academic communities, the quality of papers written by a researcher or employee is evaluated according to the estimated quality of journals in which they are published, and journal indexing and citation in particular databases is considered a significant journal quality criterion.

In spite of the rapid development of mapping science and the relevance of these

issues to all scientists, not much research has been published in this field. One of the most recent papers addresses identifying and evaluating the *GI Science* journal by applying the Delphi method [Caron et al., 2008]. An overview of some cartography and GIS journals in English was compiled by David Y. Allen, specifically concerning open-access trends and the historical development of some cartographic journals [Allen, 2005].

METHODOLOGY

In a previous study [Frančula et al., 2012], we considered mapping science journals to be those that are active, have an International Standard Serial Number (ISSN), and include content covering at least one branch of mapping science, based on the official classification of scientific areas, fields, and branches ["Croatian ordinance on scientific and artistic areas, fields and branches," 2009], which places mapping science within the technical sciences and includes the following branches: cartography, photogrammetry and remote sensing, maritime, satellite and physical geodesy, applied geodesy and geomatics. All mapping science journals that did not publish any issues in 2011 and 2012 were considered inactive and were excluded from the body of mapping science journals. Using this methodology, 105 mapping science journals were selected. To make the list of journals more accurate, for the purposes of this research, seven additional mapping science journals were added that did not satisfied the criteria defined in the previous research or that were unavailable at the time. These included *Studies in Surveying and Mapping Science* (first issue published in 2013), *Revista Cartographica* (previously considered inactive), *Geomatika = =Geomatics, Vestnik Sibirskoj gosudarstvennoj geodezičeskoj akademii (Vestnik SGGA), Geomatics and Information Sciences of Wuhan University* (previously considered inactive), *Geprofi* (previously did not have an ISSN) and the Chinese *Journal of Geomatics* (data previously unavailable). This brought the total number of mapping science journals to 112.

To begin with, the inclusion of the selected journals in well-known subject databases in this field was checked (*GEOPHOKA, Bibliographia Cartographica* and *VINITI)*. Next, we checked journal indexing using the *Dialog Classic* interface, which enabled access to several hundred databases by searching the "Journal" field. According to the number of papers found for the body of mapping science journals, we selected the most relevant subject databases (*GEOBASE, GeoRef, Inspec, Ei Compendex, Cambridge Scientific Abstracts (CSA)*, and *PASCAL)*. Indexing in the *Directory of Open Access Journals (DOAJ)* was registered, and based on our previous research, we identified a large number of mapping science journals whose content was provided in open access. Journal lists of relevant databases were consulted to register possible discrepancies in journal titles. Finally, we checked the presence of each journal in the three most popular multidisciplinary databases, *Scopus, Web of Science (WoS)* and *Google Scholar (GS),* and recorded the number of papers. We searched by "Source Title" in *Scopus*, by "Publication Name" in *WoS*, and by "Return articles published in" in an advanced search of *GS*. Categories of data for individual journals were taken from *Scopus (Subject Area)* and *WoS (Web of Science Categories)*. The *Current Contents* database was included in the research due to its popularity in the Croatian research community, as some disciplines consider journals indexed by *Current Contents* better than those indexed in *WoS,* because they are subject to more rigorous criteria set by the Thomson Reuters editorial board. The data concerning indexing were not taken directly from the journal's description, because they often proved outdated or incorrect, including cooperative library catalogues, tools for distributed searching and other irrelevant data.

For each journal, we recorded its title, ISSN, publisher, country of publication, open access (OA) status and indexing data (Appendix 1). Data on language, the scientific fields covered by the journal (*journal scope*), its subject area within *Scopus,* and *WoS* and

the number of papers in *Scopus, WoS,* and *GS* were also collected for each journal and included in the analysis. Data were collected from 1 April to 20 July 2013.

The limitations of this research primarily concerned the inability to search *GS* accurately. Although *GS Advanced search* enables searching by journal title, it is not possible to search by ISSN and consult the list of journal titles in *GS*, which made it impossible to obtain results for journals with the same titles (the Polish and Lithuanian journals *Geodesy and Cartography* and the Indian and Chinese publications *Journal of Geomatics*). We managed to identify the Lithuanian journal in *GS* by its previous title *Geodezija ir kartografija*. The journals *Globe* and *Coordinates* were impossible to identify by searching a huge number of publications with "globe" or "coordinates" in their titles. While searching, issues arose with journal titles including special characters, and were addressed by conducting multiple searches. We also detected transliterations of non-English journals titles, and obsoleteness of key data such as journal title, publisher, and ISSN in certain databases. Most databases do not contain functional data on changes in journal titles, which would provide unifying data for journals that have changed their titles. As a result, we used the journals' current titles.

INDEX PUBLICATIONS FOR THE FIELD OF MAPPING SCIENCE

The relevant index publications for the field of mapping science are primarily subject-specific databases, which cover this particular subject very well. They also include discipline-specific databases which include disciplines associated with mapping science, as well as general interest databases, which include all scientific areas.

GEOPHOKA (*GEOdäsie*, *PHOtogrammetrie*, *KArtographie*) is a bibliographic database which records papers from all fields of mapping science. It can be found at the German Federal Agency for Cartography and Geodesy website (*Bundesamt für Kartographie und Geodäsie*), and has been produced since 1984. It contains bibliographic data for approximately 65,000 papers, of which only 100 were published in 2013. Comparing this with the predicted increase of 1,300 records per year could indicate the database is obsolescent. According to the list of publications, *GEOPHOKA* indexes 92 publications, including 48 mapping science journals.

In 1957, the German Cartographic Society launched the bibliographic publication *Bibliotheca Cartographica*, which has been published since 1974 as ***Bibliographia Cartographica***, and its editorial board is linked to the *Staastbibliothek zu Berlin-PreuЯischer Kulturbesitz*. It used to be published once a year with 2,000–4,000 recorded papers. The online version has been available since 2007 and contains bibliographic data taken from journals published since 1989, while older papers can only be found in printed copies. *Bibliographia Cartographica* online contains bibliographic data for about 29,000 papers from journals and conference proceedings, and about 5,400 monographs. Around 80 international journals are regularly indexed, recording only selected papers associated with cartography, including 59 mapping science journals.

GEOBASE (Elsevier) is a multidisciplinary database which indexes about 2,000 international serial publications covering current research focused on developmental research, geoscience, ecology, geomechanics, physical geography, demogeography and oceanography. *GEOBASE* contains about 2.1 million bibliographic entries, ranging from 1973 to the present day. Its particular characteristic is good coverage of literature in languages other than English, and other types of publications, such as books, proceedings and reports.

GeoRef is produced by the American Geosciences Institute, and includes 3.4 million entries dating from 1933 to the present day. GeoRef is a bibliographic database focused

on geosciences: areal geology, economic geology, engineering geology, environmental geology, extraterrestrial geology, geochemistry, geochronology, geophysics, hydrogeology and hydrology, marine geology and oceanography, mathematical geology, mineralogy and crystallography, paleontology, petrology, seismology, stratigraphy, structural geology, and surficial geology. GeoRef includes all the publications of the U.S. Geological Survey, papers from 3,500 journals in 40 languages, and books, maps and reports. The *GeoRef* indexing policy is selective, including only papers associated with geology and related sciences.

Inspec is produced by the Institution of Engineering and Technology (IET) and includes more than 13 million entries associated with physics, astronomy, electrical engineering, electronics and computer science. Papers for this database are selected from 5,000 journals, 1,600 of which are indexed cover to cover, and 2,500 conference proceedings, books, reports, dissertations, etc.

Ei Compendex (Elsevier) is focused on engineering and related fields, and it includes 5,600 journals and 2,500 proceedings. More than 15 million entries range from 1970 to 2013, and the publications included come from more than 64 countries.

CSA databases, which used to be known as *Cambridge Scientific Abstracts* and *CSA Illustrata*, have been owned by *ProQuest* and available via *CSA Illumina* and other interfaces since 2007. CSA includes a set of databases, and we found mapping science journals in *Advanced Technologies Database with Aerospace, Aqualine, Aquatic Science & Fisheries Abstracts (ASFA), Ceramic Abstracts, Earthquake Engineering Abstracts, Environmental Engineering Abstracts, Mechanical & Transportation Engineering Abstracts, Meteorological & Geoastrophysical Abstracts, Oceanic Abstracts, Pollution Abstracts* and *Water Resources Abstracts.*

PASCAL covers the core scientific literature in science, technology and medicine and has a special emphasis on European publications. It contains more than 17 million entries from 1973 to 2013, from 3,085 international journals, proceedings, dissertations, books, patents, etc. PASCAL is produced by the *Institut de l'Information Scientifique et Technique* of the *Centre National de la Recherche Scientifique* (INIST-CNRS).

VINITI is produced by the Russian Academy of Science and primarily covers natural and technical sciences. VINITI is the largest Russian database and has a long history, including more than 25 million documents from 1952 to 2013, from more than 100 countries, written in 60 languages. VINITI is the abbreviated name of the "All Russian Institute for Scientific and Technical Information". The database is especially valuable because of its unique content, which includes so-called "grey literature" – proceedings, technical reports, etc. VINITI is an open access (OA) database available to the global research community.

Scopus (*Elsevier*) is currently one of the largest bibliographic and citation databases, established in 2004, and includes bibliographic descriptions of papers dating back to 1823, while citations are recorded from 1996. According to the comprehensive available list of included journals, *Scopus* indexes more than 31,000 publications, including about 21,000 active journals. *Scopus* employs a special subject classification, which consists of 27 main subject areas and 307 subject categories. *Scopus's* classification has five general categories, "General" and four branch categories [Guerrero-Bote & Moya-Anegón, 2012]:

- *Life Sciences* (3,950 journals): *Agricultural and Biological Sciences; Biochemistry, Genetics and Molecular Biology; Immunology and Microbiology; Neuroscience, Pharmacology, Toxicology and Pharmaceutics.*

- *Physical Sciences* (6,350 journals): *Chemical Engineering; Chemistry; Computer Science;*

Earth and Planetary Science; Energy; Engineering; Environmental Science; Materials Science; Mathematics; Physics and Astronomy.

- *Social Sciences* (5,900 journals)*: Arts and Humanities; Business, Management and Accounting; Decision Sciences; Economics, Econometrics and Finance; Psychology; Social Sciences.*

- *Health Sciences* (6,200 journals): *Medicine; Nursing; Veterinary; Dentistry; Health Professions.*

Web of Science *(WoS)* includes three citation indexes: *Science Citation Index Expanded, Social Science Citation Index* and *Arts and Humanities Citation Index,* and is published by Thomson Reuters. Nowadays, it includes about 12,500 journals from all fields of science, although biomedicine and natural sciences are represented better, as are journals from North America. Citation has been recorded since 1955, which gives it an advantage over other citation databases. *Web of Science* employs own subject classification which includes five general areas:

- *Life Sciences & Biomedicine*

- *Physical Sciences*

- *Technology*

- *Arts & Humanities*

- *Social Sciences.*

These top five areas branch out into 250 disciplines.

Current Contents *(CC) produced by Thomson Reuters* was well known in its weekly printed version published by the Institute of Scientific Information (ISI), featuring the latest information on papers from the most prominent journals. It has lost popularity in the digital age (integrated with WoS), but it is still very popular in Croatia, due to its more rigorous selectiveness, and is considered to include the most relevant scholarly journals from all scientific fields. The database currently includes about 9,500 journals, all of which are also included in the WoS database.

The Beta version of ***Google Scholar*** (*GS*) was launched in 2004, offering free, multidisciplinary access to scientific information, and one of its authors said, *"I would like Google Scholar to be a place that you can go to find all scholarly literature – across all areas, all languages, all the way back in time".* [An interview with Anurag Acharya, Google Scholar lead engineer, 2006]. *GS* includes various publications, such as journal papers, dissertations, books, proceedings, preprints, abstracts and technical reports from all disciplines. The greatest objection to *GS* is the lack of transparency concerning editorial policies, which means its harvest is unknown, but it is clear that *GS* includes an increasing amount of content by commercial publishers and database producers, e.g. ACM Portal, Taylor & Francis, Springer, Cambridge, Wiley, Blackwell, American Chemical Society (ACS), Oxford University, Sage, Emerald, Nature Publishing, Association for Computing Machinery, IEEE, American Institute of Physics, Royal Society of Chemistry, University of Chicago, ERIC, JSTOR, Project MUSE, BioMed Central, Proceedings of the National Academy of Sciences, American Medical Association, Public Library of Science [Chen, 2010; Walters, 2007; White, 2006] and many others, including well established open access (OA) models for communicating research results, such as arXiv.org [Bernius, 2013], SciELO [Packer, 2009] and the Croatian Portal of Open Access Scientific Journals HRCAK [Stojanovski, Petrak, & Macan, 2009]. *GS* also tracks citations of included papers and has gradually been able to compete with commercial citation databases such as *Scopus* and WoS. Algorithms for removing duplicates are very efficient, so one of the most valuable aspects of *GS* is the ability to view and access a particular paper via various fee and free repositories, archives and databases. Search options are very limited, as

are the possibilities of using search results, which cannot easily be sorted or stored in any standard bibliographic formats. Although a more detailed bibliographic record and improved searching would be desirable, its simplicity satisfies the requirements of most users.

RESULTS AND DISCUSSION

Indexing of mapping science journals in 14 databases

According to our data, one mapping science journal is indexed in 12 of the 14 databases analyzed (*Photogrammetric Engineering and Remote Sensing*), six are included in 11 databases (*Acta Geodaetica et Geophysica, Cartographic Journal, Journal of Geodesy, Journal of Surveying Engineering, Photogrammetric Record* and *Studia Geophysica et Geodaetica*), six are included in 10 databases (*Geodetski list, Geodetski vestnik, Geoinformatica, Geomatica, ISPRS Journal of Photogrammetry and Remote Sensing* and *Survey Review*), 18 are included in nine to seven databases, 21 are included in six or five databases, and 56 are included in four to one databases. Only four of the 112 journals were not included in any of the databases analyzed (Fig. 1).

The majority of mapping science journals (94) are included in *GS* (Table 1). Although *GS* has been criticized for its non-transparent policy, insufficient volume and structure of bibliographic entries, poor search quality, issues with diacritical signs [Harzing, 2010], overblown results, incomplete journal content, inability to identify authors and citations, inclusion of "dubious" material without scientific value, and the presence of "bibliographic absurdities" due to poor interpretation of metadata [Jacsó, 2005), this comprehensive database contains valuable information, is easy to use and its content can compete with that of many subscription-based information services [Chen, 2010; Clermont & Dyckhoff, 2012; Delgado-López-Cózar & Cabezas-Clavijo, 2013; Mayr & Walter, 2008; Meier & Conkling, 2008], so it provides a good insight into mapping science. In some cases, journal titles appear mismatched, and the list of journals included is not available with ISSNs, which makes it impossible to distinguish journals with the same name. In addition, it makes it more difficult to search shorter

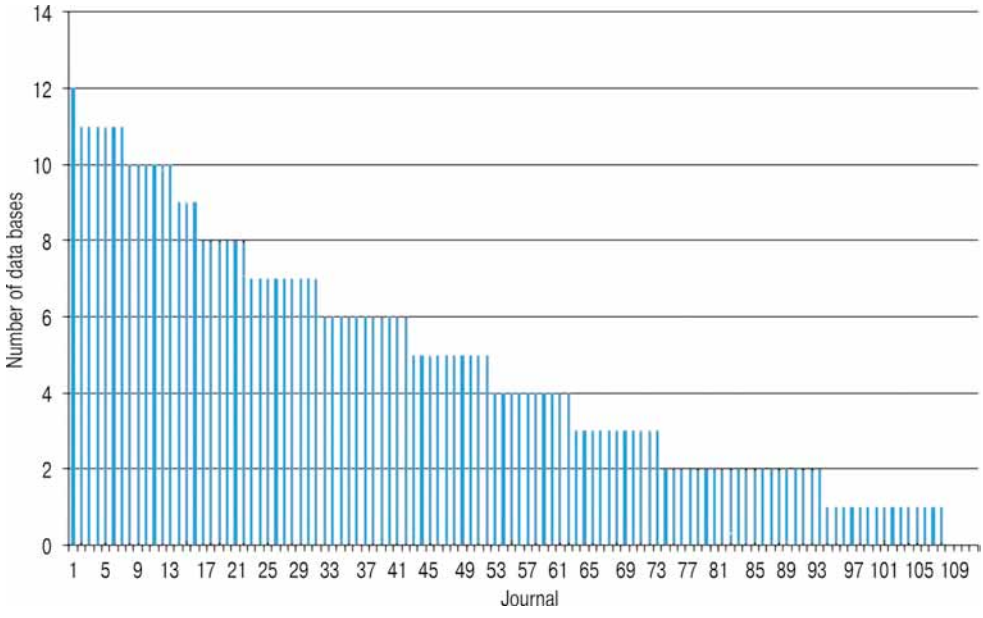

Fig. 1. Representation of mapping science journals in 14 bibliographic databases analyzed.

Table 1. Distribution of mapping science journals according to bibliographic databases

Database	# of journals	Database	# of journals
GS	94	CSA	30
Scopus	59	PASCAL	19
BC	59	*WoS*	19
GEOBASE	52	Inspec	16
GEOPHOKA	48	Compendex	13
GeoRef	48	CC	13
VINITI	42		

journal titles which may be a part of longer journal titles, especially with frequently used words. Although we attempted to detect such cases, the numbers of papers found in *GS* should be accepted with reserve.

The journals *Photogrammetric Engineering and Remote Sensing* (2,620 papers) and *Studia Geophysica et Geodaetica* (2,540 papers) are the most represented in *GS*, while as many as 25 journals are represented by fewer than 10 papers (Fig. 2), and we were unable to find any information for six journals, as their titles were too short or generic. *GS* includes a total of 30,386 papers from mapping science journals, with the average journal represented by 323 papers.

Scopus has better coverage of individual journals, indexing 57 mapping science journals, with *Photogrammetric Engineering and Remote Sensing* (3,664), *Geomatics and*

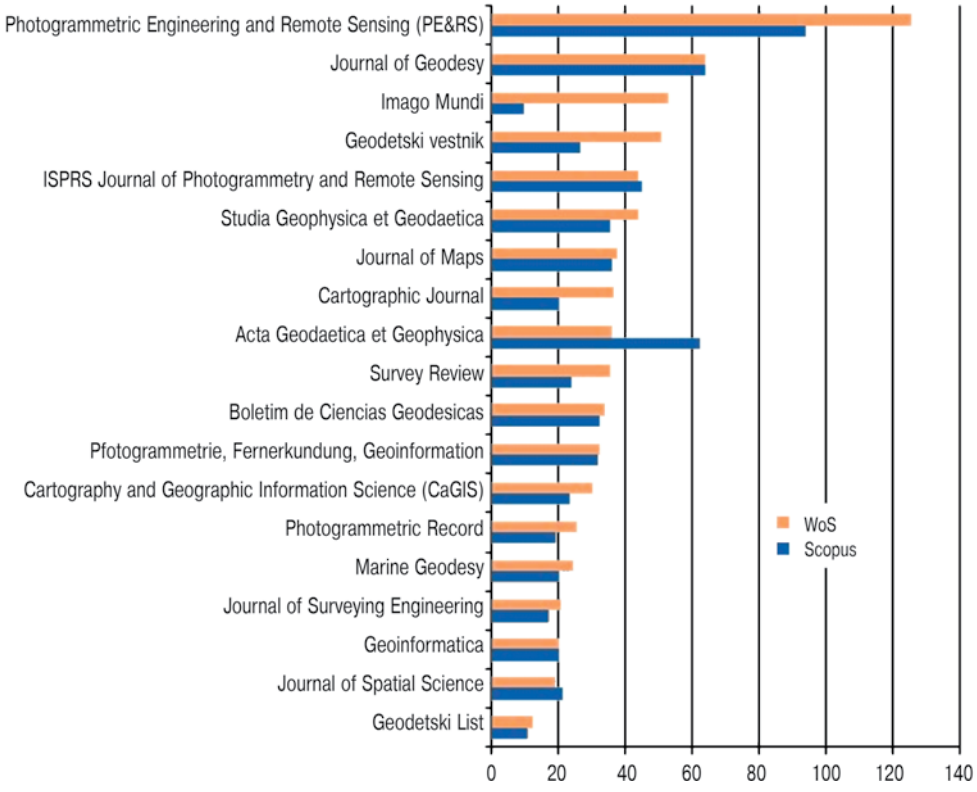

Fig. 2. Average number of papers per year in *WoS* and *Scopus* databases.

Information Science of Wuhan University (3,382) and *Studia Geophysica et Geodaetica* (2,026) the most represented. Three journals are represented by an exceptionally low number of papers in *Scopus*: *Nachrichten der Niedersächsischen Vermessungs- und Katasterverwaltung* (1), *Polski Przeglad Kartograficzny* (3) and *Geodezija i kartografija* (5). Mapping science journals are represented in *Scopus* by a total of 31,628 papers, meaning the average journal is represented by 555 papers.

WoS indexes only 19 mapping science journals, with *Photogrammetric Engineering and Remote Sensing* (5,253) and *Studia Geophysica et Geodaetica* (2,129) the most represented. The least represented journals have over 100 indexed papers, so we can conclude the database's coverage is more comprehensive. *WoS* contains the fewest papers from mapping science journals (15,204), but it includes an average of 800 papers per journal, which is more than *GS* and *Scopus*.

In subject databases, most mapping science journals are included by subject-specific and discipline-specific bibliographic databases like *Bibliographia Cartographica (59), GEOBASE (52), GEOPHOKA (48), GeoRef (48)* and *VINITI (42)*. About ten *Cambridge Scientific Abstracts (CSA)* databases include 30 mapping science journals, *PASCAL* 19, *Inspec* 17, and *Compendex* 13 (Table 1). Considering the out of date of some subject-specific databases (*Bibliographia Cartographica*, *GEOPHOKA*), it is clear that multidisciplinary databases are better at covering mapping science where newer publications are considered, and GEOBASE is the subject database which best covers mapping science.

Coverage and language comparison between Scopus and WoS

If we compare the year ranges and numbers of papers for the 19 journals indexed by *Scopus* and *WoS*, it can be seen that *Scopus* indexes a total of 447 years (14,715 papers), and *WoS* 328 years (15,204 papers). Although coverage in *WoS* is more equable in terms of time spans and existing indexing breaks (Table 2), it was somewhat surprising to discover that *WoS* coverage was not significantly better, considering *Scopus* is a relatively new database, only launched in November 2004.

Research into *Scopus* coverage indicates gaps in the cases of certain journals. Even though the editorial board has been working on this issue for some time [Meho, 2009], the problem is still present. Regardless of the longer time spans in *Scopus*, the total number of indexed papers is greater in *WoS*, as is the average number of papers per year for individual journals (Fig. 2). If we look in more detail at four journals indexed in the same time period in both databases, *Journal of Surveying Engineering* (1983–2013), *Journal of Maps* (2005–2013), *ISPRS Journal of Photogrammetry and Remote Sensing* (1989–2013) and *Journal of Geodesy* (1995–2013), we can see that only one, *ISPRS Journal of Photogrammetry and Remote Sensing* has a slightly higher number of papers in *Scopus* than in *WoS*. Regarding all the mapping science journals included in both databases, *Scopus* has a significantly better coverage only for *Acta Geodaetica et Geophysica*. Although the numbers are slightly in favor of WoS, considering *WoS* as a product with a long, detailed history (we used the WoS time span covering 1955 to present), we expected much better coverage from this database.

Another 40 *Scopus* journals are covered in the range from 3,382 papers (for *Geomatics and Information Science of Wuhan University)* to one (for *Nachrichten der Niedersächsischen Vermessungs- und Katasterverwaltung)*. In addition, ten mapping science journals were identified in *Scopus* which are currently considered inactive, presumably due to irregular publication and/or poor citations (years of journals with data in *Scopus* are in parentheses): *AVG – Allgemeine Vermessungs-Nachrichten* (1979–1980, 1988–1994), *ACSM Bulletin* (1989–1996), *Caert Thresoor* (1982–1991), *Geodeticky a kartograficky obzor* (1978–1980, 1982–1989), *Geodezia es Kartografia* (1979–1981, 1988–1989, 1991–1992, 1995–2007), *Geodezija i Kartografija* (1979), Kart og

Table 2. Mapping science journals coverage in *Scopus* and *WoS* databases

Journal	*Scopus* year range	*Scopus* # years	*Scopus* # papers	*WoS* year range	*WoS* # years	*WoS* # papers
Acta Geodaetica et Geophysica	2003–2013	11	681	2007–2013	7	249
Boletim de Ciencias Geodesicas	2005–2013	9	291	2008–2013	6	203
Cartographic Journal	1979–2013	35	701	1988–2013	26	939
Cartography and Geographic Information Science (CaGIS)	1997–2013	17	397	2009–2012	4	121
Geodetski list	1979–1983, 1985, 2008–2013	12	128	2007–2011	7	86
Geodetski vestnik	1992–2013	22	583	2007–2013	7	355
Geoinformatica	1997–2013	17	337	2001–2013	13	262
Imago Mundi	1977–1986, 1988–1990, 1994–1997, 2001, 2005–2013	27	253	2009–2012	4	211
ISPRS Journal of Photogrammetry and Remote Sensing	1989–2013	25	1114	1989–2013	25	1099
Journal of Geodesy	1995–2013	19	1207	1995–2013	19	1211
Journal of Maps	2005–2013	9	322	2005–2013	9	336
Journal of Spatial Science	2004–2013	10	211	2007–2013	7	134
Journal of Surveying Engineering	1983–2013	31	528	1983–2013	31	642
Marine Geodesy	1979–1994, 1996–2013	34	676	1980–1989, 2003–2013	21	510
Photogrammetric Engineering and Remote Sensing (PE & RS)	1975-2013	39	3664	1972–2013	42	5253
Photogrammetric Record	1979–2013	35	660	1983–2013	31	779
Photogrammetrie, Fernerkundung, Geoinformation	2009–2013	5	157	2008–2013	6	194
Studia Geophysica et Geodaetica	1957–2013	57	2026	1965–2013	49	2129
Survey Review	1980, 1982–2013	33	779	2000–2013	14	491

Plan (1978–1979, 1982–1989), *Nachrichten der Niedersächsischen Vermessungs- und Katasterverwaltung* (1978), *Photogrammetric Journal of Finland* (1978–1979, 1982, 1984, 1986, 1989–1992), *Polski Przeglad Kartograficzny* (1982) and *Przeglad geodezyjny* (1979–1981).

Among the journals indexed in *WoS*, only three (16%) publish papers in a language other than English (Croatian, Portuguese and Slovenian). *Scopus* indexes 22 (55%) journals which publish papers in a language other than English. Among 53 journals not indexed by *Scopus* and *WoS*, 19 (36%) publish papers in English, and 34 (64%) in other languages – 10 in German, five in French, three in Russian, and 16 in other languages. *WoS* includes only a limited number of mapping science journals in languages other than English, while more than half the mapping science journals indexed by *Scopus* are not in English.

Open Access

We had expected to find the majority of open access journals in *GS,* according to earlier research [Neuhaus, Neuhaus, Asher, & Wrede, 2006], and this proved to be correct. Out of 47 open access mapping science journals, 41 can be found in GS, which is 44% of the total GS mapping science journals. However, deeper probing reveals data less favored by to GS, e.g. 12 journals are represented by 10 or less papers. To be crawled by GS, journal web sites should meet some technical requirements, but many open access journals are not following the GS guidelines for publishers. We noticed that the fifth most

represented open access journal, according to the number of papers, was *Cartography and Geoinformation*, whose contents are harvested from the central Croatian scientific journals portal HRCAK, which includes about 340 open access journals at the present. *GS* is harvesting more easily aggregators that host many journals on a single website.

GEOPHOKA includes 19 open access journals (40% of all indexed mapping science journals), Bibliographia Cartographica 22 (37%), CSA 11 (37%), VINITI 13 (31%), Scopus 18 (31%), GEOBASE 15 (29%), GeoRef 13 (27%), EI Compendex 3 (23%), WoS 4 (21%), PASCAL 3 (16%), Current Contents 1 (8%), and Inspec 1 (6%) respectively.

We were surprised that only eight of the 47 mapping science journals were registered in the Directory of Open Access Journals (DOAJ). The reason for this probably lies in the criteria for inclusion set by DOAJ; the editorial board and affiliations are listed as well as a detailed review procedure, instructions for authors, a clear, detailed open access policy, requiring at least five papers published each year, access to metadata, full text and references without restrictions, registration with SHERPA/RoMEO, etc. DOAJ and its advisory committee have worked systematically to improve journals' editorial policies. For a number of open access mapping science journals, the lack of vital information on their websites was observed. Very often, an entire volume is available as a single document, instead of individual papers. The way mapping science journals display their content is often according to the printed form, while the digital version is not adapted for online usage and screen reading.

Subject classification

The classification of publications within the subject categories used by various index publications can be objected to on many grounds. The subject categories for *WoS* and *Scopus* were analyzed in detail for the purposes of this research. These two classification schemes are the most popular, especially *WoS*'s, which is often used in bibliometric analyses. In addition, subject categories in both *WoS* and *Scopus* are attributed to journals, not papers [Waltman & van Eck, 2012]. Thus, in contrast to databases with more specialized coverage, such INSPEC, where papers are directly assigned to categories, under the *WoS* or *Scopus* classification model, journals are classified into categories, while papers are assigned to source categories through indirect assignation [Gómez-Núñez, Vargas-Quesada, Moya-Anegón, & Glänzel, 2011]. This is certainly inadequate for interdisciplinary fields [Herranz & Ruiz-Castillo, 2012; Waltman & van Eck, 2012] such as mapping science. In addition, although both the *WoS* and *Scopus* subject classifications include all scientific fields and are similar in volume (250 *WoS*, 307 *Scopus*), they vary significantly by content, so it is frequently impossible to match *WoS* and *Scopus* subject categories.

Categorization analysis according to scientific disciplines indicates that mapping science journals are categorized in *Scopus* and *WoS* databases in different categories. Some journals are categorized in more than one category, which makes finding and comparing them difficult. Since most mapping science journals have data on journal scope, a simple text analysis was conducted which identified the most frequent terms used by editorial boards to described their journals' subject coverage: *geodesy, cartography, surveying, remote, sensing, photogrammetry, GIS, mapping, land, geoinformation, spatial, geographic, geodetic, maps, geomatics*, etc., while the most frequent phrases were *remote sensing, geographic information systems*, *land management, spatial data*, etc. Journal scope was not available for seven mapping science journals.

Both *Scopus* and *WoS* employ their own classification schemes, starting with several general categories which branch out into subcategories. The *WoS* scheme has two, while the *Scopus* scheme has three hierarchical levels. Their production and maintenance is exclusively related to database coverage and is not at all transparent, and thus cannot be compared with classification schemes such as those used by *LCC* (*Library of Congress Classification*) or

MESH (*Medical Subject Headings*), which are produced by expert teams, and for which each term is described in detail, and continuous and systematic work is carried out to introduce new terms and remove obsolete ones. The classification schemes used by WoS and Scopus cannot be matched even at the top level of general categories. *Scopus* employs a hierarchical taxonomy of subject categories which consists of five general categories: *General, Physical Sciences, Health Sciences, Social Sciences* and *Life Sciences,* while *WoS* also employs five general categories: *Life Sciences & Biomedicine, Physical Sciences, Technology, Arts & Humanities* and *Social Sciences.* While there are some similarities among the general categories, there are none among the subcategories. Within the *Physical Sciences* category, used by both databases, *Scopus's* taxonomy contains ten, and *WoS*'s twenty scientific disciplines, only two of which overlap: *Chemistry* and *Mathematics*.

The second level of *Scopus's* classification scheme contains 27 scientific disciplines, with mapping science journals categorized in eight of them:

Physical Sciences: Computer Science (6), Earth and Planetary Sciences (53), Energy (1), Engineering (10), Environmental Science (12) and *Physics and Astronomy (1),* and *Social Sciences: Business, Management and Accounting (1)* and *Social Sciences (11)*.

The third level of subject categories in the *Scopus* classification scheme contains 307 categories. The discipline *Earth and Planetary Sciences,* where the greatest number of mapping science journals are categorized, contains 12 categories. Among 53 journals categorized in this discipline, only 30 have a category assigned to them, while others are simply assigned to *Earth and Planetary Sciences (all)* (Table 3). We did not discover the reason why subject categories were overlooked. Even if a journal covered all the fields included in *Earth and Planetary Sciences*, it might simply be labeled as "miscellaneous".

For journals indexed by *Scopus*, the categorization of 16 mapping science journals

Table 3. Example of distribution of mapping science journals at the third hierarchical level of the *Earth and Planetary Sciences* subject category (*Scopus*)

Earth and Planetary Sciences (all)	# of journals
Earth and Planetary Sciences (miscellaneous)	7
Atmospheric Science	1
Computers in Earth Sciences	6
Earth-Surface Processes	7
Economic Geology	0
Geochemistry and Petrology	2
Geology	1
Geophysics	4
Geotechnical Engineering and Engineering Geology	0
Oceanography	1
Palaeontology	0
Space and Planetary Science	1
Stratigraphy	0

in the categories *Earth and Planetary Sciences* (*miscellaneous*) and *Geography, Planning and Development* is justified. However, it is difficult to understand why *Cartography and Geographic Information Science* is categorized under *Business, Management and Accounting: Management of Technology* and not under *Earth and Planetary Sciences* (*miscellaneous*) and *Social Sciences: Geography, Planning and Development*. Furthermore, the *ISPRS Journal of Photogrammetry and Remote Sensing* is only categorized under *Information Systems*, but not under *Earth and Planetary Sciences* (*miscellaneous*). The same is true for *Geodetski vestnik*, which is categorized under *Geography, Planning and Development*, but not under *Earth and Planetary Sciences* (*miscellaneous*). It is also unclear why only five mapping science journals are included in *Computers in Earth Sciences*, which should contain most mapping science journals, or why this category containing only 17 journals even exists, since nowadays each subject category should have a "*Computers in...*" subcategory. All authors publishing papers in *Earth Sciences* journals use computer technology in their research. The usefulness of the category is further undermined by the

fact that it does not include the *Computers & Geosciences* journal, which specializes in applying computers in geosciences.

We found several mapping science journals indexed by *Scopus*, had no subject categories, even at the top level, for unknown reasons: *GIM International*, *International Journal of Geoinformatics* and *Journal of the Korean Society of Surveying Geodesy Photogrammetry and Cartography*.

As with *Scopus*, the *WoS* categorization does not include a mapping science category, so mapping science journals are categorized in 12 different categories, which differ significantly from those in *Scopus*. The categories include: *Engineering, Civil; Geochemistry & Geophysics; Geosciences, Multidisciplinary; Geography; Geography, Physical; Geology*; *History*; *History & Philosophy of Science*; *History of Social Sciences; Imaging Science & Photographic Technology; Oceanography* and *Remote Sensing*. Groups *Geography, History*, *History & Philosophy of Science* and *History of Social Sciences* are within *Social Science Edition*, and all other categories are within *Science Edition*. Only the *Journal of Maps* is included in both. Sometimes it is difficult to ascertain why some journals are categorized in those categories, e.g. why *Geodetski vestnik* is assigned to *Geography* (*Social Science Edition*) and *Geodetski list* to *Remote Sensing* (*Science Edition*). Both *Geodetski list* and *Geodetski vestnik* publish papers in all fields of mapping science, so categorizing them within *Geosciences, Multidisciplinary* would make the most sense. Both journals publish approximately the same number of papers about remote sensing, so categorizing them both under *Remote Sensing* would also be logical.

Categorizing all mapping science journals in one comprehensive subject group (e.g. *Mapping science*) would make them more visible. Equalizing WoS and Scopus classification schemes covering the same number of areas (first level) and subject categories (second level) would be a great advantage for all bibliometric studies [Gómez-Núñez et al., 2011]. Also, assigning subject categories to papers and not only to journals would help locating mapping science papers.

CONCLUSIONS AND FUTURE RESEARCH

If the criteria for visibility and ease of locating journals include open access and availability via popular topical and multidisciplinary databases, we can conclude there is a lot of room for improvement when it comes to mapping science journals. The inclusion of journals in topical and multidisciplinary online databases, most of which developed from printed index and abstract publications, is a prerequisite for easy location, but proof of serious, professional editorial work is also required with respect to improving editorial standards. Among the 112 mapping science journals selected, only 28% were indexed in more than half of the databases analyzed, while four journals were not found in. *Google Scholar* included the highest number of mapping science journals (94), while *Scopus, Bibliographia Cartographica, GEOBASE, GEOPHOKA, GeoRef* and *VINITI* each included about fifty. Other databases included between 30 and 13 mapping science journals.

The journals most represented by numbers of papers in *Google Scholar, Scopus* and *Web of Science* were *Photogrammetric Engineering and Remote Sensing, Geomatics and Information Science of Wuhan University* and *Studia Geophysica et Geodaetica*. The analysis indicates that *Web of Science* has continuously covered the included journals; *Scopus* has gaps in its coverage, and *Google Scholar* covers many titles (25) insufficiently (fewer than 10 papers).

Among 47 open access mapping science journals, only eight featured in the *Directory of Open Access Journals (DOAJ)*, which may be attributed to the high criteria set by DOAJ. Open access journals were well represented in GS, GEOPHOCA, Bibliographia Cartographica, CSA, VINITI and Scopus (over 30% of all mapping science journals included. A detailed analysis of open access mapping science journals indicated a lack of vital information on their

websites, as well as the strong influence of printed version of journals, manifest in the formats of digital versions of journals which have not been adapted for online use. Regarding journal language, it could be seen that *Scopus* also indexes many journals which publish papers in languages other than English.

Categorizing mapping science journals within the subject categories assigned in citation databases like *WoS* and *Scopus* does not contribute to their visibility. The interdisciplinary nature of mapping science journals results in their dispersion among numerous subject categories in applied classification schemes. A comparison of the subject areas assigned to journals by database indexers with the subject areas which editorial boards communicate to potential authors, indicates that database administrators should certainly consult *journal scope* when attributing subject areas. In addition, using a unified subject designation such as "mapping science" would facilitate finding mapping science journals. Assigning subject categories at the level of papers could also provide higher visibility for research in this area, as well as enable better bibliometric studies.

Future research will focus on the analysis of metric indicators of the body of mapping science journals, including Journal Impact Factor (JIF), SCImago Journal Rank (SJR), SNIP, Eigenfactor Score, h-index, etc., as well as altmetrics indicators. In addition, mapping science journals will be compared with journals from other disciplines, in order to observe their characteristics and specifics. ■

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Appendix 1. Journals included in the research with corresponding indexing data

Journal title	ISSN	Publisher	Country	OA	DOAJ	GEOB	GeoR	Comp	Insp	PASC	CSA	VINI	GEOP	BC	Scop	WoS	CC	GS
ACSM Bulletin	0747-9417	American Congress on Surveying and Mapping	USA	Yes	0	0	1	0	0	0	0	0	1	0	1	0	0	1
Acta Geodaetica et Cartographica Sinica	1001-1595	Cehui Chubanshe	China	Yes	0	1	0	0	0	0	1	1	1	1	1	0	0	1
Acta Geodaetica et Geophysica	2213-5812	Springer; Akadémiai Kiadó	Hungary	No	0	1	1	1	1	0	1	1	1	1	1	1	0	1
AVN = Allgemeine Vermessungs-Nachrichten	0002-5968	Wichmann-Verlag	Germany	No	0	1	1	0	1	0	1	0	1	1	1	0	0	1
Applied Geomatics	1866-9298	Springer	Germany	No	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Artificial Satellites	0208-841X	Versita	Poland	Yes	0	0	0	1	0	0	1	1	1	0	1	0	0	1
Association of Canadian Map Libraries and Archives Bulletin	0840-9331	Association of Canadian Map Libraries and Archives	Canada	Yes	0	1	1	0	0	0	0	0	0	1	1	0	0	1
Boletim de Ciencias Geodesicas	1413-4853	Universidade Federal do Paraná	Brazil	Yes	1	1	1	0	0	0	1	1	0	0	1	1	0	1
Bollettino della Associazione Italiana di Cartografia	0044-9733	Associazione Italiana di Cartografia	Italy	No	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Bulletin du Comité Francais de Cartographie	0755-7647	Comité français de cartographie	France	No	0	0	1	1	0	0	0	0	0	1	0	0	0	1
Bulletin of the Geospatial Information Authority of Japan	2185-3681	The Geospatial Information Authority of Japan (GSI)	Japan	Yes	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Bulletin of the Society Cartographers	1469-5170	Society of Carthographers	Great Britain	No	0	1	1	0	0	0	0	1	0	1	1	0	0	1
Caert Thresoor	0167-4994	Barent Langenes Foundation	The Netherlands	No	0	1	0	0	0	0	0	0	0	1	1	0	0	1
Cartes & géomatique	2119-9825	Comité Français de Cartographie	France	No	0	0	0	0	0	1	0	0	0	1	0	0	0	0

Continue

Journal title	ISSN	Publisher	Country	OA	DOAJ	GEOB	GeoR	Comp	Insp	PASC	CSA	VINI	GEOP	BC	Scop	WoS	CC	GS
Cartographic Journal	0008-7041	Maney Publishing	Great Britain	No	0	1	1	0	0	1	1	1	1	1	1	1	1	1
Cartographic Perspectives	1048-9053	North American Cartographic International Society	USA	Yes	0	1	1	0	0	0	0	1	0	1	1	0	0	1
Cartographica Helvetica	1015-8480	Verlag Cartographica Helvetica	Switzerland	No	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Cartographica: The International Journal for Geographic Information and Geovisualization	0317-7173	University of Toronto Press	Canada	No	0	1	1	0	0	1	0	1	1	1	1	0	0	1
Cartography and Geographic Information Science (CaGIS)	1523-0406	International Cartographic Association (ICA)	USA	No	0	1	1	1	0	0	0	1	0	1	1	1	1	1
Contributions to Geophysics and Geodesy	1335-2806	Versita	Poland	Yes	0	1	1	0	0	0	0	1	0	0	1	0	0	1
Coordinates: A monthly magazine on positioning, navigation and beyond	0973-2136	Centre for Geo-Information Technologies (cGIT)	India	Yes	0	0	0	0	0	0	0	0	1	0	0	0	0	1
e-Perimetron	1790-3769	Hellenic National Centre for Maps and Cartographic Heritage	Greece	Yes	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Flächenmanagement und Bodenordnung (FuB)	1616-0991	Chmielorz	Germany	No	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Geo: connexion	1476-8941	GeoConnexion Ltd.	Great Britain	No	0	1	0	0	0	0	0	0	0	0	1	0	0	1
Geo-Info	1572-5464	Geo-Informatie Nederland	The Netherlands	Yes	0	1	0	0	0	0	0	0	0	1	1	0	0	1
Geo-spatial Information Science	1009-5020	Wuhan University, Taylor & Francis	China	No	0	1	1	0	1	0	1	1	1	1	1	0	0	1
Geodesy and Cartography	2029-6991	Taylor & Francis Co-Published with Vilnius Gediminas Technical University	Lithuania	No	0	1	0	1	0	0	1	1	1	0	1	0	0	1

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Journal title	ISSN	Publisher	Country	OA	DOAJ	GEOB	GeoR	Comp	Insp	PASC	CSA	VINI	GEOP	BC	Scop	WoS	CC	GS
Geodesy and Cartography	2080-6736	Polish Academy of Sciences	Poland	Yes	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Geodeticky a kartograficky obzor	0016-7096	Česky urad zememericky a katastralni	Czech	Yes	0	0	0	0	0	0	0	0	1	1	1	0	0	0
Geodetska služba	1451-0561	Republički geodetski zavod Srbije	Serbia	Yes	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Geodetski glasnik	1512-6102	Savez udruženja grapana geodetske struke Bosne i Hercegovine	Bosnia and Herzegovina	Yes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Geodetski list	0016-710X	Hrvatsko geodetsko društvo	Croatia	Yes	1	1	1	0	0	0	1	1	1	1	1	1	0	1
Geodetski vestnik	0351-0271	Zveza geodetov Slovenije	Slovenia	Yes	1	1	1	0	0	0	1	1	1	1	1	1	0	1
Geodetski Žurnal	1451-2602	Savez geodeta Srbije i Savez geodetskih in Ženjera i geomatara Srbije	Serbia	No	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Geodezia es Kartografia	0016-7118	Kartografiai Vallalat	Hungary	No	0	1	1	0	0	1	0	1	1	1	1	0	0	1
Geodezija i kartografija	0016-7126	Kartgeocentr – Geodezizdat	Russia	No	0	1	0	0	0	1	0	1	1	1	1	0	0	1
Geoinformatica	1384-6175	Kluwer Academic Publishers	The Netherlands	Yes	0	1	0	1	1	1	1	1	0	0	1	1	1	1
Geoinformatics	1387-0858	CMedia B. V.	The Netherlands	Yes	0	0	1	0	0	0	1	0	1	1	0	0	0	1
Geoinformation issues = Problemy Geoinformacji	1689-6440	Institute of Geodesy and Cartography, Warshaw	Poland	Yes	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Geomatica	1195-1036	Canadian Institute of Geomatics	Canada	No	0	1	1	1	0	1	1	1	1	1	1	0	0	1
Geomatics and Environmental Engineering	1898-1135	Akademia Gorniczo-Hutniczej im. Stanislawa Staszica w Krakowie	Poland	Yes	0	0	0	0	0	0	0	0	0	0	0	0	0	1

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Journal title	ISSN	Publisher	Country	OA	DOAJ	GEOB	GeoR	Comp	Insp	PASC	CSA	VINI	GEOP	BC	Scop	WoS	CC	GS
Geomatics and Information Science of Wuhan University	1671-8860	Wuhan University	China	No	0	1	1	0	1	0	0	1	0	1	1	0	0	1
Geomatics Workbooks	1591-092X	Laboratorio di Geomatica – Politecnico di Milano – Polo di Como	Italy	Yes	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Geomatik Schweiz = Géomatique Suisse = Geomatica Svizzera	1660-4458	Sigimedia	Switzerland	Yes	0	0	0	0	0	0	0	0	1	1	0	0	0	1
Geomatika = Geomatics	1691-4341	Riga Technical University	Latvia	Yes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Géomatique Expert	1620-4859	CiMax	France	No	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Geprofi	2306-8736	Informacionnoe agentstvo GROM	Russia	Yes	0	0	0	0	0	0	0	1	0	0	0	0	0	1
GIM International	1566-9076	Geomares Publishing	The Netherlands	Yes	0	1	1	0	0	0	1	1	1	0	1	0	0	1
GIS-Business	1430-3663	Wichmann Verlag	Germany	No	0	1	0	0	0	0	0	0	1	1	1	0	0	1
Globe	0311-3930	Australian and New Zealand Map Society	Australia	No	0	0	1	0	1	0	0	0	0	1	0	0	0	n.a.
Globe Studies	0436-0664	The International Coronelli Society	Austria	No	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Godišnjak Geodetskog društva Herceg-Bosne	1840-3816	Geodetsko društvo Herceg Bosne	Bosnia and Herzegovina	Yes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Imago Mundi	0308-5694	Taylor & Francis, Routledge	USA	No	0	1	1	0	0	0	0	1	0	1	1	1	1	1
Information Bulletin	0049-7282	Western Association of Map Libraries	USA	No	0	0	1	0	0	0	0	0	0	1	1	0	0	1
International Journal of Geoinformatics	1686-6576	Asian Institute of Technology	Tayland	No	0	1	1	0	0	0	0	1	0	0	1	0	0	1
ISPRS International Journal of Geo-Information	2220-9964	MDPI AG	Switzerland	Yes	1	0	0	1	0	1	1	0	0	0	0	0	0	1

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Journal title	ISSN	Publisher	Country	OA	DOAJ	GEOB	GeoR	Comp	Insp	PASC	CSA	VINI	GEOP	BC	Scop	WoS	CC	GS
ISPRS Journal of Photogrammetry and Remote Sensing	0924-2716	Elsevier	The Netherlands	No	0	1	1	0	1	0	1	1	1	0	1	1	1	1
Izvestija VUZov. Geodezija i aerofotos'emka	0536-101X	MIIGAiK	Russia	Yes	0	0	1	0	0	0	0	1	1	1	0	0	0	1
Journal of Applied Geodesy	1862-9016	Walter de Gruyter	Germany	No	0	1	0	0	1	0	1	0	1	0	0	0	0	1
Journal of Geodesy	0949-7714	Springer	Germany	No	0	1	1	0	1	1	1	1	1	0	1	1	1	1
Journal of Geodetic Science	2081-9919	Versita	Poland	Yes	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Journal of Geomatics	1007-3817	Wuhan University	China	No	0	1	1	0	1	0	1	1	0	1	1	0	0	1
Journal of Geomatics	0976-1330	Indian Society of Geomatics	India	No	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Journal of Map and Geography Libraries	1542-0353	Taylor & Francis	USA	No	0	1	1	0	0	0	1	0	0	1	1	0	0	1
Journal of Maps	e1744-5647	Taylor & Francis	USA	No	0	0	1	0	1	0	0	1	0	0	1	1	1	1
Journal of Spatial Science	1449-8596	Taylor & Francis	USA	No	0	1	1	0	0	1	0	0	0	0	1	1	0	1
Journal of Surveying Engineering	0733-9453	American Society of Civil Engineers	USA	No	0	1	1	1	1	1	1	1	0	0	1	1	1	1
Journal of the Geodetic Society of Japan	0038-0830	Geodetic Society of Japan	Japan	No	0	1	1	0	0	0	0	1	1	0	1	0	0	1
Journal of the Korean Society of Surveying Geodesy Photogrammetry and Cartography	1598-4850	Korean Society of Surveying Geodesy Photogrammetry and Cartography	Republic of Korea	nepoznato	0	1	0	0	0	0	0	1	0	0	1	0	0	1
Kart & Bildteknik = Mapping and Image Science	1651-792X	Kartografiska Sällskapet	Sweden	Yes	0	1	0	0	0	0	0	0	0	1	1	0	0	1
Kart og Plan	0047-3278	Fagbokforlaget	Norway	No	0	1	0	1	0	0	1	0	1	1	1	0	0	1

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Journal title	ISSN	Publisher	Country	OA	DOAJ	GEOB	GeoR	Comp	Insp	PASC	CSA	VINI	GEOP	BC	Scop	WoS	CC	GS
Kartograficke listy	1336-5274	Cartographic Society of the Slovak Republic	Slovakia	No	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Kartografija i Geoinformacije = Cartography and Geoinformation	1333-896X	Hrvatsko kartografsko društvo	Croatia	Yes	1	1	0	0	0	0	1	0	1	1	1	0	0	1
Kartographische Nachrichten	0022-9164	Kirschbaum Verlag	Germany	No	0	1	1	0	0	0	0	0	1	1	1	0	0	1
LSA VERM – Zeitschrift für das Öffentliche Vermessungswesen des Landes Sachsen-Anhalt	1435-2338	Landesaamt für Vermessung und Geoinformation Sachsen-Anhalt	Germany	No	0	0	0	0	0	0	0	0	1	1	0	0	0	0
M@ppemonde	1769-7298	Maison de la géographie	France	Yes	1	1	0	0	0	1	0	1	0	1	1	0	0	1
Maanmittaus	0047-5319	Helsinki, Valtioneuvoston kirjapaino	Finland	Yes	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Map : Journal of the Japan Cartographers Association	0009-4897	Japan Cartographers Association	Japan	No	0	0	1	0	0	0	0	0	1	1	0	0	0	0
Marine Geodesy	0149-0419	Taylor & Francis	USA	No	0	1	1	0	0	1	1	1	0	0	1	1	1	1
Mitteilungen der DVW-Landesvereine Hessen e.V. und Thüringen e.V.	0949-7900	DVW Hessen und Thüringen	Germany	Yes	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Mitteilungen des DVW-Bayern e.V.	1613-3064	DVW Landesverein Bayern	Germany	No	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Mitteilungen des DVW-Landesvereins Baden-Württemberg	0940-2942	DVW Landesvereine Baden-Württemberg	Germany	No	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Nachrichten aus dem offentlichen Vermessungswesen (NOEV)	1863-4176	Innenministerium des Landes Nordrhein Westfalen	Germany	Yes	0	0	0	0	0	0	0	0	1	1	0	0	0	0

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Journal title	ISSN	Publisher	Country	OA	DOAJ	GEOB	GeoR	Comp	Insp	PASC	CSA	VINI	GEOP	BC	Scop	WoS	CC	GS
Nachrichten der Niedersächsischen Vermessungs- und Katasterverwaltung	0487-5370	Niedersächische Vermessung und Katasterverwaltung	Germany	No	0	1	0	0	0	0	0	0	1	0	1	0	0	0
Nordic journal of surveying and real estate research	1459-5877	The Finnish Society of Surveying Sciences	Finland	Yes	0	0	0	0	0	0	0	0	1	1	0	0	0	1
Österreichische Zeitschrift für Vermessung und Geoinformation	1605-1653	Österreichische Gessselschaft für Vermessung und Geoinformation	Austria	No	0	0	1	0	0	0	0	0	1	0	0	0	0	1
Photogrammetric Engineering and Remote Sensing (PE & RS)	0099-1112	American Society of Photogrammetry and Remote Sensing	USA	No	0	1	1	1	1	1	1	1	1	0	1	1	1	1
Photogrammetric Journal of Finland	0554-1069	The Finnish Society of Photogrammetry and Remote Sensing	Finland	Yes	0	1	1	0	0	0	0	0	0	0	1	0	0	1
Photogrammetric Record	0031-868X	Remote Sensing and Photogrammetry Society	Great Britain	No	0	1	1	1	1	1	1	1	0	0	1	1	1	1
Photogrammetrie, Fernerkundung, Geoinformation	1432-8364	Schweizerbart Science Publishers	Switzerland	No	0	0	0	0	0	0	0	1	1	1	1	1	0	1
Polski Przeglad Kartograficzny	0324-8321	Polskie Towarzystwo Geograficzne. Oddzial Kartograficzny	Poland	No	0	1	1	0	0	1	0	0	0	1	1	0	0	1
Portolan, The	1096-1925	Washington Map Society	USA	No	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Professional Surveyor Magazine	0278-1425	Flatdog Media, Inc.	USA	Yes	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Przeglad geodezyjny	0033-2127	Stowarzyszenia Geódetow Polskych	Poland	No	0	1	0	0	0	1	1	0	1	1	1	0	0	0

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Journal title	ISSN	Publisher	Country	OA	DOAJ	GEOB	GeoR	Comp	Insp	PASC	CSA	VINI	GEOP	BC	Scop	WoS	CC	GS
Publication in Geomatics = Geomatikai Közlemények	1419-6492	Geodetic and Geophycical Institute, Hung. Acad. Sci	Hungary	Yes	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Reports on Geodesy	0867-3179	Warsaw University of Technology / Faculty of Geodesy and Cartography	Poland	Yes	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Revista Brasileira de Cartografia	0560-4613	Sociedade Brasileira de Cartografia, Geodesia, Fotogrammereia, e Sensoriamento Remoto	Brazil	Yes	1	0	1	0	0	0	0	0	0	1	0	0	0	1
Revista cartografica	0080-2085	Instituto Panamericano de Geografia e Historia	Mexico	No	0	0	1	0	0	0	0	0	0	1	0	0	0	1
Revue Francaise de Photogrammetrie et de Teledetection	1768-9791	Société Française de Photogrammétrie et de Télédétection	France	No	0	0	0	1	0	1	0	1	0	0	1	0	0	1
Revue Internationale de Géomatique	1260-5875	Hermes Science	France	No	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Roczniki Geomatyki = Annals of Geomatics	1731-5522	Polskie Towarzystwo Informacji Przestrzennej	Poland	No	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Sheetlines	0962-8207	The Charles Close Society	Great Britain	Yes	0	0	0	0	0	0	0	0	0	1	0	0	0	1
South African Journal of Geomatics	2225-8531	CONSAS Conference	Republic of Suthafrica	Yes	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Studia Geophysica et Geodaetica	0039-3169	Springer	Germany	No	0	1	1	0	1	1	1	1	1	0	1	1	1	1

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Journal title	ISSN	Publisher	Country	OA	DOAJ	GEOB	GeoR	Comp	Insp	PASC	CSA	VINI	GEOP	BC	Scop	WoS	CC	GS
Studies in Surveying and Mapping Science	2328-6245	American Society of Science and Engineering	USA	Yes	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Survey Review	0039-6265	Maney Publishing	Great Britain	No	0	1	1	0	1	0	1	1	1	0	1	1	1	1
Surveying and Land Information Science (SaLIS)	1538-1242	American Congress on Surveying and Mapping	USA	No	0	1	0	0	0	0	0	1	0	1	1	0	0	1
Topografia y cartografia	0212-9280	Colegio Oficial de Ingenieros Técnicos en Topografia de Madrid	Spain	No	0	0	1	0	0	0	0	0	1	1	0	0	0	0
Vermessung Brandenburg	1430-7650	Landesvermessung und Geobasisinformation Brandenburg	Germany	Yes	0	0	0	0	0	0	0	0	1	1	0	0	0	1
Vestnik Sibirskoj gosudarstvennoj geodezičeskoj akademii (Vestnik SGGA)	1818-913X	Sibirskaja gosudarstvenaja geodezičeskaja akademija	Russia	No	0	0	0	0	0	0	0	1	0	0	0	0	0	0
XYZ	0290-9057	Association Française de Topographie	France	No	0	0	1	0	0	0	0	0	1	1	0	0	0	1
ZfV – Zeitschrift fur Geodasie, Geoinformation und Landmanagement	1618-8950	Deutscher Verein für Vermessungswesen e.V.	Germany	Yes	0	1	0	0	0	0	0	1	1	1	1	0	0	1

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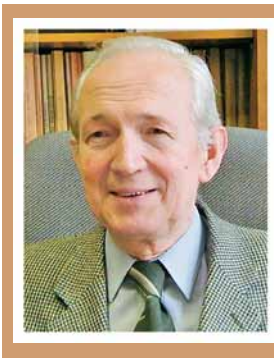

Nedjeljko Frančula is professor emeritus at the Faculty of Geodesy, University of Zagreb. While working on the application of computers for solving geodetic and cartographic problems for more than 30 years, he introduced digital cartography into the undergraduate and postgraduate studies at the Faculty of Geodesy in Zagreb. He has been a full member of the Croatian Academy of Engineering in Department of Civil Engineering and Geodesy since 1998. In March 2008 he has been named Member Emeritus. He published about 500 scientific and professional papers.

Miljenko Lapaine studied Mathematics and graduated from the Faculty of Science, University of Zagreb. He completed the postgraduate studies in Geodesy in the field of Cartography at the Faculty of Geodesy in Zagreb by defending his Master's thesis A Modern Approach to Map Projections. He obtained his PhD from the same Faculty with a dissertation entitled Mapping in the Theory of Map Projections. He has been a full professor since 2003. Prof. Lapaine is the chairman of the ICA Commission on Map Projections, a founder and president of the Croatian Cartographic Society and the executive editor of the Cartography and Geoinformation journal. He has published more than 800 papers, several textbooks and monographs.

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HEAVY METALS IN MAPLE AND DANDELION LEAVES FROM DIFFERENT LAND-USE AREAS IN MOSCOW'S EASTERN DISTRICT

ABSTRACT. This article is based on extensive biogeochemical research conducted in Moscow's Eastern Administrative District, where motor-vehicle traffic and heavy industry have resulted in some of the highest levels of pollution in the city. For this study, 26 samples of maple leaves (*Acer platanoides*) and 49 samples of dandelion leaves (*Taraxacum officinale*) were collected on a regular grid at 500–700 m intervals. Concentrations of Fe, Mn, Mo, Cd, Pb, Zn, Cu, As and Sb in these plants were measured using atomic absorption spectrometry after washing, drying and HNO_3 + H_2O_2 digestion. Maples accumulated $Sb_{9,7}As_{4,6}Mo_{2,2}Fe_{2,0}Zn_{1,5}Pb_{1,4}Cu_{1,2}$, while dandelions accumulated $Mo_{12,7}Pb_{4,9}Cd_{4,4}Fe_{4,3}As_{3,9}Sb_{2,7}Cu_{1,4}$ — normalized to concentrations in background samples from an unpolluted site west from Moscow. The plants' geochemical specialization was detected and compared in the following land-use areas: industrial, traffic, recreational, agricultural, and high-, mid-, and low-rise residential development. For maples, the highest concentration factor levels were found in industrial areas, with accumulations of $Sb_{19}As_{2,4}Mo_{1,7}Zn_{1,7}Fe_{1,5}Cu_{1,4}Pb_{1,4}$. These levels were 2–5 times lower for maples in other land-use areas. Dandelions and maples do not accumulate Mn because of antagonism between Zn, Mo and Mn in soils. Copper is not concentrated by herbaceous species because of antagonism between Mo and Cu. Differences in geochemical specialization were shown using the Sb/Mo ratio: in dandelions this was 5 times lower than in background samples, while in maples it was 4.5 times higher. A Z_v ratio was used to evaluate the intensity of biogeochemical transformation in urban plants. The highest Z_v ratios were found in plants near industrial zones and large roads.

KEY WORDS: heavy metals and metalloids, urban plants, dandelion, maple, Moscow, ecogeochemistry.

INTRODUCTION

Cities are often sites of concentrated pollution resulting from dense population and industrial production. In Russia, as in many countries worldwide, the ecological situation in urban areas is near critical [Bityukova et al., 2011]. Cities consume 75% of the world's resources while occupying only 2% of the land. More than half the world's population — 3.6 billion people — now live in urban areas, and by 2025 this population is projected to reach 58%, or 4.6 billion people [World Urbanization Prospects, 2011]. In Russia, 73% of the population — 103 million people — live in 1,060 cities and 2,070 townships [Ekologiya..., 2004].

Pollutants accumulate in various parts of the urban landscape, including soil, atmospheric dust, snow cover, water, plants and animals. In studying urban pollution, heavy metals and

metalloids (HM) are particularly important. Plants can be used to monitor urban pollution, as they accumulate HM through their leaves and roots [Deu & Kreeb, 1993; Bargagli, 1998]. Leaves absorb elements more selectively than roots [Kvesitadze et al., 2005]. Urban biomonitoring is often conducted with maple leaves [Smith, 1973; Lepneva & Obukhov, 1987; Piczak et al., 2003; Kosiba, 2009; Tomašević et al., 2011] and dandelion leaves [Kuleff & Djingova, 1984; Lepneva & Obukhov, 1987; Djingova & Kuleff, 1999; Marr et al., 1999; Czarnowska, Milewska, 2000; Winter et al., 2000; Keane et al., 2001; Krolak, 2003; Shishlova & Khristoforova, 2009; Hussain & Khan, 2010; Klinskaya & Khristoforova, 2011; Gjorgieva et al., 2011; Malizia et al., 2012].

Research on HM accumulation focuses mainly on Mn, Fe, Pb, Cu, Zn, Cd and As, with only a few studies that include Sb and Mo [Kuleff & Djingova, 1984; Winter et al., 2000; Kosiba, 2009]. Antimony, the companion element of arsenic, has unknown biological functions and some researchers consider it potentially toxic to living organisms. It is also classified as a priority pollutant by the European Union and the United States Environmental Protection Agency, and is on the list of hazardous compounds banned as a result of the Basel Convention [Bargagli, 1998; Shtangeeva et al., 2011; Bech et al., 2012]. Yet some scientists are unsure about the ecotoxicity of antimony [Filella et al., 2009], or even claim that its mutagenic, carcinogenic and teratogenic risks are not highly significant [Leonard & Gerber, 1996]. Molybdenum, on the other hand, is an essential element [Bargagli, 1998; Alloway, 2013] despite its relatively low physiological necessity for plants [Kabata-Pendias, 2011]. Human use of these elements is increasing, as evident in their accelerated rates of production [Kasimov & Vlasov, 2014].

Among the major industrial centers in Russia, Moscow is one of the most polluted [Ekogeokhimiya..., 1995]. Its Eastern Administrative District (EAD) is known as the main industrial area, with dozens of enterprises located on its territory. Comprehensive geochemical investigation in the EAD began during the 1980s under E.M. Nikiforova and other scientists from the Landscape Geochemistry and Soil Geography Department at Lomonosov Moscow State University [Nikiforova & Lazukova, 1991]. This research continued under E.M. Nikiforova, N.E. Kosheleva and N.S. Kasimov. Over more than 20 years, these scientists have assembled substantial data on the migration and accumulation of HM in different landscape components and functional areas [Kosheleva et al, 2005; Nikiforova et al., 2010; Kasimov et al., 2012].

Biogeochemical assessment of HM pollution was conducted in the district between 1989 and 1991 [Nikiforova & Lazukova, 1995]. This included investigating the accumulation of Fe, Mn, Zn, Cu, Pb, Cd, Ni, Co and Cr in unwashed samples of poplar and linden (both leaves and branches), mowed grasses (*Elymus repens*, *Deschampsia cespitosa*, *Agrostis vulgaris* reed and ground) and dandelions, as well as samples of cabbage, fennel, corn, carrots, barley and oats in home gardens. This study determined that poplar leaves accumulate HM more intensively than linden leaves. Plants in industrial zones showed the highest levels of contamination. Along railways, poplar leaves accumulated Fe, Mn, Zn, Pb, while herbaceous species accumulated Rb, Cr, Cs and Pb. In residential areas, the most concentrated metals were Zn, Pb, Ni, Cr, Cs and Rb [Nikiforova & Lazukova, 1995]. There were high levels of contamination in the EAD among crops such as dill (Zn, Cr, Ni, Cu), cabbage (Zn, Cs), corn (Cr, Zn, Pb), potatoes (Zn) and grain (Ni). Fieldwork conducted in 2005 revealed spatial and temporal trends in lead accumulation by plants in the district [Nikiforova et al., 2010].

The present study focuses primarily on biogeochemical characteristics found in washed samples of maple and dandelion leaves, determining the rate of geochemical transformation for plants in comparison with background samples, and identifying spatial

differences in the accumulation of Mn, Fe, Pb, Cu, Zn, Cd, Mo, Sb and As.

MATERIAL AND METHODS

Study area and sampling. This study was carried out in the southern EAD over the first ten days of July 2010. The main source of anthropogenic impact in Moscow is motor-vehicle transportation. In the EAD there are also a range of industrial operations, which include energy processing, metalwork, mechanical engineering, chemical production, textile manufacturing, building-material production, and incineration (Fig. 1).

For the current study, levels of HM were detected in leaves of woody (maple, *Acer platanoides*) and herbaceous (dandelion, *Taraxacum officinale*) plants. Samples of 5–7 maples and 15–20 dandelions were taken at different locations and a mixed-sample of each species was prepared. Seven types of land use were studied (Fig. 1): industrial & non-residential, traffic, recreational, agricultural and residential development with high- (over 9 floors), mid- (6–9 floors) and low-rise (1–5 floors) buildings [Kasimov et al., 2012]. In all, 26 sites with maples and 49 sites with dandelions were sampled. Plant material was collected on a regular grid with at 500–700 m intervals. At each site, maple leaves were taken from a height of 2 m above ground at different quarters of the tree crown after more than 5 days without rain, as recommended [Bargagli, 1998]. Approximately 125 g of plant material was taken at each location. The same types of plants were sampled near the town of Zvenigorod, 40 km west of Moscow, to serve as a background sample. This location of background sites was chosen to minimize impact from Moscow according to the main west wind direction.

Fig. 1. Sampling sites in areas with different types of land use in the southern part of Moscow's Eastern Administrative District. Figure based on published work [Kasimov et al., 2012b; Bolshoi Atlas Moskvy, 2012] and data collected through the present study

Laboratory technique and analysis. Maple leaf petioles were separated from leaf blades in the laboratory. The blades and dandelion leaves were then rinsed with distilled water to remove deposited dust from their surface. Rinsed leaves were air-dried for 5 hours, and then the samples were dried in an oven at 75 °C for 5 hours.

Plant material was digested in Teflon autoclaves using extra-pure nitric acid and hydrogen peroxide (4:1). It was then heated in stages at the following temperatures: 160 °C for 1 hour, 200 °C for 2 hours, and 180 °C for 1 hour. This material was cooled and diluted to 25 ml with deionized water.

Detection and measurement of Fe, Mn, Mo, Cd, Pb, Zn, Cu, As and Sb was carried out using flame atomic absorption spectrometry (novAA-400, Analytik-Jena AG, Germany and AA-240Z, Varian Inc., USA) in the Ecogeochemical Research and Educational Center at Lomonosov Moscow State University.

RESULTS AND DISCUSSION

Levels of heavy metals and metalloids in maple and dandelion leaves. For maples, mean concentrations of Fe, Pb, Cu, Mo, Sb and As in background samples were lower than their average concentrations in terrestrial plants (Table 1). Mn, Zn and Cd concentrations, on the other hand, were higher in background samples than average for terrestrial plants. A somewhat different situation was encountered in dandelions: mean concentrations of Fe, Mn, Pb, Cu, Mo, Sb and As were lower in background samples, while Cd was slightly higher and Zn was substantially higher than average concentrations in terrestrial plants [Perel'man & Kasimov, 1999].

On the other hand, levels of all elements except Mn and Cd in maples, and Mn and Zn in dandelions, were higher in the EAD than outside Moscow. This was due to antagonism between Mn, Zn, Mo and other elements in soils, as well as increasing soil alkalinity [Nikiforova et al., 2010; Kabata-Pendias, 2011]. P.V. Elpatievsky found similar results among urban oaks. He also found that maximum concentrations of Mn were reached just before leaf fall among urban oaks, and in midsummer among non-urban oaks [Elpatievsky, 1993]. That is because plants on non-polluted areas accumulate Mn faster than on polluted territories. Thus, lower concentrations of Mn for urban versus non-urban maples in the present study may be due to sampling leaves at midsummer. Copper is not concentrated by herbaceous species because of antagonism between Mo and Cu, i.e. the physiological barrier to Mo uptake by plants is much less effective than that to Cu uptake [Kabata-Pendias, 2011].

Concentrations of heavy metals and metalloids in urban maple leaves are highly variable for different land uses (Table 1). The highest average concentrations of Fe, Pb, Mo, Sb and As in plant material were found in industrial areas: 756, 2.8, 0.034, 0.103 and 0.01 mg per kg of dry weight, respectively. The highest average concentrations of Fe, Pb and Sb were found in dandelions at industrial sites: 417, 1.5 and 0.024 mg per kg of dry weight, respectively. The main industrial sources of Fe are emissions from metalwork and mechanical engineering; for Pb they are energy processing, metalwork, mechanical engineering, textile manufacturing, chemical production, and incineration; for Mo they are energy processing, metalwork and mechanical engineering; for Sb they are metalwork, mechanical engineering, chemical production, textile manufacturing, building-material production, and incineration; for As they are energy processing, metalwork, chemical production, and incineration [Ekologiya..., 2004; Bezuglaya & Smirnova, 2008].

There were high levels of Sb among maples in transportation areas, averaging 0.089 mg per kg of dry weight. Average levels of Mn, Zn, Cu and Cd in maples were highest near roads: 569, 67, 7.8 and 0.2 mg per kg, respectively. Concentrations of these

Table 1. Heavy metals and metalloids concentrations (mg/kg dry weight) in maple and dandelion leaves from different land-use areas in the EAD, compared with samples from the Moscow region and average composition for these plants

Territory (*n*)	Maple leaves, *Acer platanoides*								
	Fe	Mn	Pb	Zn	Cu	Cd	Mo	Sb	As
Industrial & non-residential area (3)	756 (182–1286)	405 (113–696)	2.8 (0.8–5.2)	65 (56–72)	7.0 (6.3–7.7)	0.12 (0.06–0.20)	0.034 (0.026–0.050)	0.103 (0.007–0.232)	0.010 (0.004–0.02)
Traffic area (3)	165 (88–293)	569 (274–779)	1.3 (1.2–1.5)	67 (56–74)	7.8 (7.3–8.3)	0.20 (0.09–0.38)	0.011 (0.007–0.013)	0.089 (0.049–0.168)	0.003 (0.002–0.004)
High-rise buildings (2)	176 (174–178)	152 (147–158)	0.66 (0.33–0.98)	49 (47–51)	7.7 (7.3–8.1)	0.11 (0.06–0.15)	0.007 (0.005–0.009)	0.067 (0.054–0.079)	0.010 (0.008–0.011)
Mid-rise buildings (4)	112 (71–140)	566 (395–906)	1.2 (1.0–1.5)	58 (40–78)	6.0 (3.6–8.4)	0.14 (0.08–0.17)	0.013 (0.006–0.021)	0.036 (0.010–0.074)	0.003 (0.001–0.006)
Low-rise buildings (8)	194 (85–345)	498 (138–641)	1.1 (0.3–1.6)	63 (35–83)	6.2 (4.5–8.6)	0.11 (0.06–0.16)	0.009 (0.002–0.028)	0.028 (0.005–0.065)	0.004 (0.001–0.007)
Recreational area (6)	122 (77–213)	548 (165–1077)	1.2 (0.7–1.4)	56 (19–85)	7.3 (6.3–8.8)	0.22 (0.06–0.64)	0.013 (0.002–0.028)	0.014 (0.001–0.036)	0.005 (0.002–0.010)
EAD (26)	225 (71–1286)	491 (113–1077)	1.3 (0.3–5.2)	60 (19–85)	6.8 (3.6–8.8)	0.15 (0.06–0.64)	0.014 (0.002–0.05)	0.045 (0.001–0.23)	0.005 (0.001–0.015)
Control samples from Moscow region (5)	110 (94–135)	826 (204–1060)	0.93 (0.62–1.32)	40 (29–54)	5.7 (5.3–6.8)	0.26 (0.05–0.43)	0.006 (0.001–0.024)	0.005 (0.001–0.011)	0.001 (0.001–0.002)
Territory	**Dandelion leaves, *Taraxacum officinale***								
	Fe	**Mn**	**Pb**	**Zn**	**Cu**	**Cd**	**Mo**	**Sb**	**As**
Industrial & non-residential area (7)	417 (147–853)	122 (74–215)	1.5 (0.60–3.3)	32 (21–62)	6.6 (6.1–7.2)	0.21 (0.09–0.42)	0.39 (0.25–0.58)	0.024 (0.003–0.066)	0.008 (0.002–0.018)
Traffic area (7)	255 (66–510)	153 (102–247)	0.89 (0.71–1.2)	34 (19–58)	6.3 (5.9–6.8)	0.67 (0.12–2.7)	0.49 (0.07–1.8)	0.018 (0.005–0.044)	0.003 (0.001–0.005)
Agricultural area (5)	113 (35–262)	251 (120–326)	0.45 (0.14–0.65)	51 (7.8–109)	8.6 (6.5–15)	1.7 (0.37–2.9)	0.57 (0.06–1.6)	0.007 (0.001–0.021)	0.002 (0.001–0.004)
High-rise buildings (6)	156 (78–188)	167 (113–248)	0.68 (0.12–0.95)	54 (20–152)	6.3 (4.5–7.1)	0.45 (0.22–0.67)	0.32 (0.022–0.51)	0.005 (0.001–0.013)	0.003 (0.001–0.008)
Mid-rise buildings (6)	197 (134–251)	144 (126–158)	0.77 (0.16–1.3)	39 (20–81)	6.0 (3.5–6.9)	0.80 (0.25–3.1)	0.49 (0.35–0.85)	0.021 (0.004–0.047)	0.011 (0.003–0.038)
Low-rise buildings (11)	169 (27–358)	136 (75–215)	0.62 (0.044–1.7)	50 (16–148)	6.3 (5.8–6.8)	0.46 (0.052–1.0)	0.30 (0.05–1.0)	0.011 (0.002–0.040)	0.005 (0.002–0.009)
Recreational area (7)	196 (117–471)	163 (99–260)	0.74 (0.45–1.1)	42 (29–71)	6.5 (5.7–7.1)	1.2 (0.19–3.4)	0.57 (0.40–0.86)	0.021 (0.003–0.054)	0.009 (0.001–0.023)
EAD (49)	215 (27–853)	157 (74–326)	0.81 (0.044–3.3)	43 (7.8–152)	6.6 (3.5–15)	0.72 (0.052–3.4)	0.43 (0.022–1.8)	0.015 (0.001–0.066)	0.006 (0.001–0.038)
Control samples (5)	50 (18–171)	177 (150–204)	0.17 (0.10–0.24)	46 (30–63)	4.6 (3.3–5.4)	0.16 (0.10–0.22)	0.034 (0.028–0.043)	0.006 (0.002–0.011)	0.002 (0.001–0.004)
Parameter	**Terrestrial plants**								
	Fe	**Mn**	**Pb**	**Zn**	**Cu**	**Cd**	**Mo**	**Sb**	**As**
Average composition of terrestrial plants[a]	150	350	1.5	6.3	10	0.15	0.8	0.04	1.5

[a]Perel'man & Kasimov, 1999.

elements were high among dandelions in transportation areas, but lower than in industrial and agricultural areas. As reported by Lough et al. [2005], Thorpe & Harrison [2008] and Limbeck & Puls [2011], the main sources of Mn in transportation emissions are wearing of brake pads and resuspension of soil particles; for Zn and Sb they are motor oil emissions and wearing of tires and brake pads; for Cu they are exhaust and motor oil emissions as well as wearing of tires and brake pads; for Cd they are wearing of tires.

Only dandelions were sampled at agricultural sites, where their mean concentrations of Mn, Cu, Cd and Mo were higher than in other land-use areas. Highest average levels of Zn were found in dandelions around high-rise buildings, while for Mo they occurred in recreational areas. However, the same concentrations of Zn and Mo were found in agricultural areas. Their presence in agricultural fields was due to the use of phosphate fertilizers [Yanin, 1999].

Table 2 compares maple-leaf composition in the EAD with maple-leaf composition in other cities. Concentrations of Mn were higher than in other cities, while levels of Cu were lower. Fe and Pb levels were lower than in other cities except Waibrzych and Wrociaw, Poland. For Zn and Cd, concentrations were slightly higher or almost even with other cities. There is relatively little information on Mo, As and Sb concentrations in urban maple leaves, which prevented us from identifying significant differences between their presence in the EAD and in other cities. For herbaceous species (Table 2), concentrations of Mn in dandelions from the EAD were higher than in other cities, while concentrations of Cu and Pb were lower. Levels of Cd, Fe and Zn were either higher or lower in the EAD than in other cities. It should be noted that, as with maples, there is insufficient information about Mo, As and Sb levels in urban dandelions.

Urban versus non-urban concentrations of pollutants can be compared using the enrichment factors (*EF*) ratio: $EF = C/C_b$, where C is the element concentration in an urban plant, and C_b is the concentration of the same element in the reference (background) plant. The depletion factor (DF) is the reverse index of EF: DF = 1/EF. The depletion factor can only be used when EF < 1.

Fig. 2. Shows levels of EF and DF for chemical elements in maple and dandelion leaves in areas with different types of land use. The mean EF of chemical elements in EAD maples was (hereafter, the subscript number shows the EF value) $Sb_{9,7}As_{4,6}Mo_{2,2}Fe_{2,0}Zn_{1,5}Pb_{1,4}Cu_{1,2}$, while in dandelions it was $Mo_{12,7}Pb_{4,9}Cd_{4,4}Fe_{4,3}As_{3,9}Sb_{2,7}Cu_{1,4}$.

The main feature of maples found in each land-use area was strong Sb accumulation. Moreover, high EF values were calculated for As in all land use areas. Industrial areas had the highest levels of the following elements: $Sb_{22}As_{9,2}Fe_{6,8}Mo_{5,4}Pb_{3,1}$. These pollutants are contained in emissions from energy processing, metalwork, mechanical engineering, chemical production and incineration plant located in the EAD [Bezuglaya & Smirnova, 2008]. These elements — as along with Cu and Zn — are also emitted by automobiles, which is why maple leaves in traffic areas contain high concentrations: $Sb_{19}As_{2,4}Mo_{1,7}Zn_{1,7}Fe_{1,5}Cu_{1,4}Pb_{1,4}$. Residential buildings of different heights correspond with different elements at maximum CF: Sb, As and Cu for high-rise developments, Mo for mid-rise, and Fe for low-rise. This may be a result of different lengths of time in which soil has been accessible to contamination. For example, the most-polluted soils are found in areas with old low-rise development, whereas the least-contaminated soils are in newer developments where high-rise buildings predominate [Nikiforova et al., 2011].

The main difference between dandelions and maples is strong Mo accumulation in all types of land-use areas by herbaceous plants. Moreover, Cd had high EF values in all land-use areas except industrial. Cu concentrations in herbaceous plants from all areas in the EAD are slightly higher than

Table 2. Heavy metals and metalloids concentrations (mg/kg dry weight) in maple leaves from the EAD compared with concentrations in maple leaves from other cities

Territory, season, pollution source, washed/unwashed, sample preparation, analysis technique, number of samples *n*	Mn	Fe	Cu	Pb	Zn	Cd	Mo	As	Sb	Reference
Maple leaves Acer platanoides										
EAD, industry and traffic, summer, washed, $HNO_3 + H_2O_2$ digestion, AAS, $n = 26$	491 (113–1077)	225 (71–1286)	6.8 (3.6–8.8)	1.3 (0.3–5.2)	60 (19–85)	0.15 (0.06–0.64)	0.01 (0.002–0.05)	0.005 (0.001–0.015)	0.04 (0.001–0.23)	Our data
Parks and Botanical Garden, Belgrade, Serbia, summer, traffic, unwashed, $HNO_3 + H_2O_2$ digestion, ICP-MS, $n = 15$	296	640	22	7.4	35	0.09	–	0.55	–	Tomašević et al., 2011
–//– washed	303	357	9.8	5.3	32	0.217	–	0.46	–	–//–
Poland (different voivodeships), summer, industry and traffic, washed, ashing + HNO_3, AAS, $n = 45$	120 (23–853)	264 (25–2975)	8.5 (1.6–24)	9.3 (0.30–34)	57 (14–165)	0.85 (0.01–3.0)	1.6 (0.21–4.1)	–	–	Kosiba, 2009
Waibrzych and Wroclaw, SW Poland, summer, traffic, washed, $HNO_3 + H_2O_2$ digestion, ICP-AES, $n = 3$	174	170	7.5	0.67	52	0.17	–	–	–	Piczak et al., 2003
–//– autumn	319	278	8.6	6.1	84	3.0	–	–	–	–//–
Territory of Lomonosov Moscow State University, Moscow, summer, traffic, ashing, AAS	–	–	7,5	2,7	7,5	0,3	–	–	–	Lepneva, Obukhov, 1987
New Haven, Connecticut, USA, autumn, traffic, unwashed, ashing + HNO_3, AAS, $n = 32$	414 (69–1799)	512 (186–1349)	9 (0.5–31)	146 (45–485)	142 (28–429)	1.1 (0.5–2.0)	–	–	–	Smith, 1973
Dandelion leaves Taraxacum officinale										
EAD, industry and traffic, summer, washed, $HNO_3 + H_2O_2$ digestion, AAS, $n = 49$	157 (74–326)	210 (4–853)	6.6 (3.5–15)	0.8 (0.05–3.3)	43 (8–152)	0.72 (0.05–3.4)	0.43 (0.02–1.8)	0.01 (0.001–0.04)	0.02 (0.001–0.07)	Our data
Wislinka, Northern Poland, autumn, phosphogypsum stack, unwashed, $HNO_3 + H_2SO_4$ digestion, ICP-OES, $n = 3$	–	421	38	174	69	–	–	–	–	Boryio et al., 2013
Rome, Italy, spring, traffic, washed, HNO digestion 3, ICP-AES, $n = 15$	64	–	30	8	102	–	–	–	–	Malizia et al., 2012
–//– summer	49	–	36	15	113	–	–	–	–	–//–
–//– autumn	37	–	33	8	77	–	–	–	–	–//–
Veles, Macedonia, lead and smelting plant, summer, washed, $HNO_3 + H_2O_2$ digestion, ICP-AES	~59	–	~10	~45	~135	7.2	–	–	–	Gjorgieva et al., 2011

Cont.

Territory, season, pollution source, washed/unwashed, sample preparation, analysis technique, number of samples *n*	Mn	Fe	Cu	Pb	Zn	Cd	Mo	As	Sb	Reference
Birobidzhan, Russia, traffic	–	–	–	7.6	0.9	0.35	–	–	–	Klinskaya, Khristoforova, 2011
Khabarovsk, Russia, traffic	–	–	–	4.9	–	0.3	–	–	–	–//–
Vladivostok, Russia, traffic	–	–	–	14	3.4	1.4	–	–	–	–//–
Cengio, Savona, Italy, waste dump of a chemical factory, washed, HNO_3 digestion, ICP-MS	50	146	13	0.9	143	0.2	–	0.1	–	Massa et al., 2010
Peshawar, Pakistan, washed, ashing + HNO_3, AAS	2.7	32	1.4	5	–	–	–	–	–	Hussain, Khan, 2010
Ussuriysk, summer, traffic, metalwork, unwashed, $HNO_3 + H_2SO_4$ digestion, AAS, n = 4	77	394	19	11	50	0.35	–	–	–	Shishlova, Khristoforova, 2009
Poland (South and East), spring, metallurgy, washed, $HNO_3 + H_2O_2$ digestion, AAS, *n* = 35	–	–	44	24	161	1.2	–	–	–	Krolak, 2003
Cincinnati, Ohio, USA, autumn, traffic, washed, ashing + HCl + HNO_3, ICP-AES, *n* = 6	83 (30–114)	1569 (155–3916)	22 (9–58)	19 (1–45)	97 (51–180)	1.6 (0.6–3.1)	–	–	–	Keane et al., 2001
Zittau, Germany, spring, traffic, washed, $HNO_3 + H_2O_2$ digestion, ICP-OES, *n* = 57	29	116	14	1.1	46	0.21	1.7	0.47	–	Winter et al., 2000
Warsaw suburbs, Poland, spring, traffic, washed, ashing + HCl, AAS, *n* = 16	28	410	15	9	86	1.1	–	–	–	Czarnowska, Milewska, 2000
Montreal, Canada, old industrial areas, washed, HNO_3 digestion, AAS, ICP-AES, *n* = 4	26	–	9	7	95	1.0	–	–	–	Marr et al., 1999
Sofia, Bulgaria, spring-autumn, traffic, washed, HNO_3 + HCl digestion, ICP-AES, *n* = 14	21	–	12	1.5	56	0.45	–	–	–	Djingova, Kuleff, 1999
Territory of Lomonosov Moscow State University, Moscow, summer, traffic, ashing, AAS	–	–	3.6	4.1	13.5	2.8	–	–	–	Lepneva, Obukhov, 1987
Sofia, Bulgaria, summer, traffic, washed, NAA	–	–	–	–	69	0.93	–	1.7	0.19	Kuleff, Djingova, 1984
Unpolluted territories of Europe	56	260	14	1.8	44	0.23	–	0.16	–	Bargagli, 1998
Unpolluted territories of Europe and the USA	15–200	60–500	5–20	0.3–6	30–100	0.2–0.8	0.6–2.9	0.1–0.4	–	Djingova et al., 2004

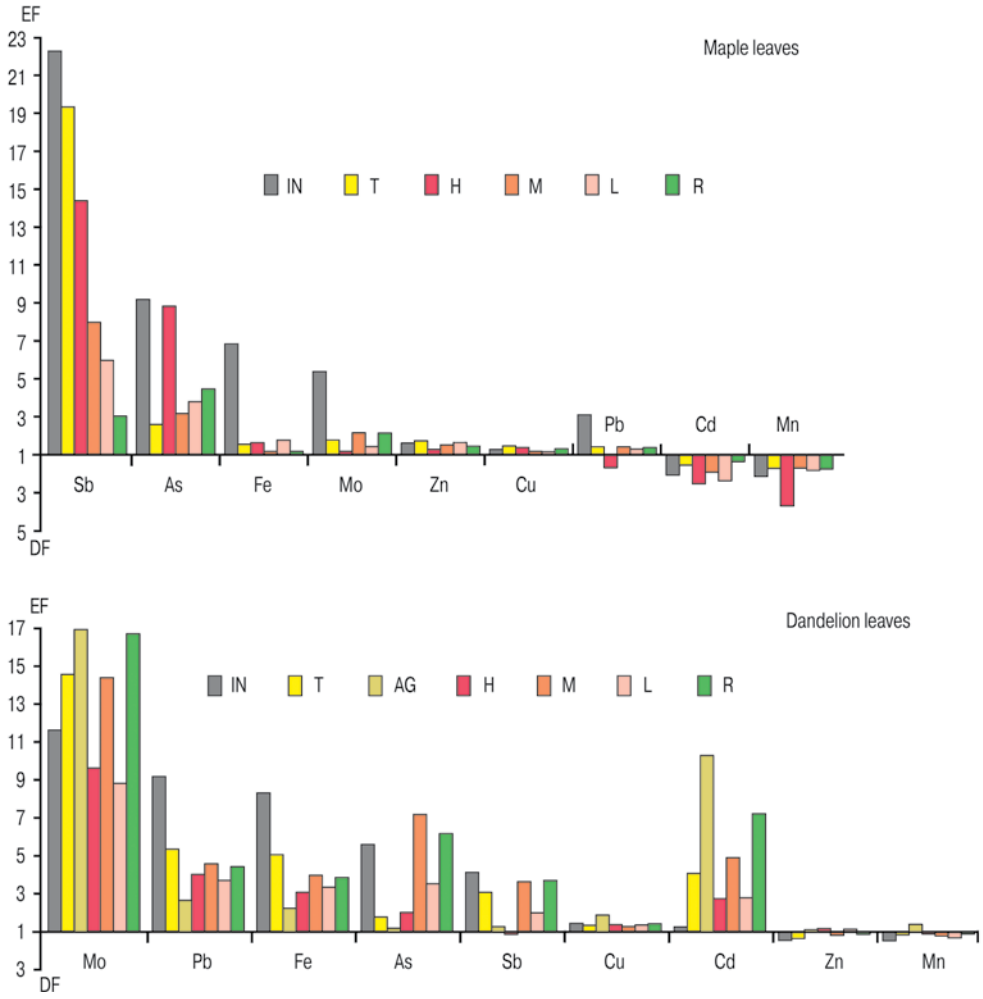

Fig. 2. Levels of EF and DF for chemical elements in the EAD maple and dandelion leaves. Types of land use:

IN — industrial and non-residential, T — traffic, AG — agricultural, H — high-rise buildings, M — mid-rise buildings, L — low-rise buildings, R — recreational

in background dandelions, while Zn and Mn are slightly lower. The highest EF levels in industrial areas were found in Pb, Fe, As and Sb. In traffic areas, the highest were in Pb, Fe and Sb. In agricultural areas they were in Pb and Fe. Recreational areas as well as low-rise and mid-rise developments showed high EF levels in dandelions for each element except Cu, Mn and Zn. Concentrations of all elements in dandelions around high-rise buildings were lower than in other areas. There were higher EF levels in dandelions than in woody plants. This can be explained by the fact that dandelions take nutrients and microelements from the soil's surface layer, which is the most polluted, whereas maples draw from deeper layers [Nikiforova et al., 2011].

The ratio of toxic to essential elements. An element is essential if it participates in the metabolism of a living organism and cannot be substituted by another element in performing biochemical roles. For terrestrial plants, the elements Cu, Fe, Mn, Mo and Zn are essential, while Cd, As, Sb and Pb are toxic or nonessential [Bargagli, 1998]. Mechanisms of the various interactions between HM in

plants and soils are not-well understood [Kabata-Pendias, 2011].

Key functions of urban plants can be represented using Fe/Mn and Pb/Mn ratios. The Fe/Mn ratio shows the intensity of photosynthesis, while Pb/Mn represents the consumption of anthropogenic and biophilic elements [Arzhanova & Elpatievsky, 1990; Novikova & Kosheleva 2007; Kasimov et al., 2011].

Table 3. Ratios of chemical elements in maple and dandelion leaves from the EAD in relation to background plants

Ratios	IN		T		AG	H		M		L		R		EAD	
	1	2	1	2	1	1	2	1	2	1	2	1	2	1	2
Fe/Mn	12.0	13.9	5.9	2.2	1.6	3.3	8.7	4.8	1.5	4.3	2.9	4.2	1.7	4.8	3.4
Pb/Mn	13.3	6.3	6.2	2.0	1.9	4.3	3.9	5.7	1.9	4.8	2.0	4.8	1.9	5.5	2.4
Zn/Mn	1.0	3.3	0.9	2.4	0.8	1.2	6.6	1.0	2.1	1.4	2.6	1.0	2.1	1.1	2.5
Cu/Mn	2.1	2.5	1.6	2.0	1.3	1.5	7.3	1.6	1.5	1.8	1.8	1.6	1.9	1.6	2.0
Cd/Mn	1.8	0.9	4.7	1.1	7.2	2.9	2.2	6.0	0.8	3.6	0.7	7.8	1.3	4.9	1.0
As/Mn	8.0	18.8	2.1	3.4	0.8	2.1	47.7	8.8	4.6	4.5	6.3	6.7	6.7	4.4	7.8
Sb/Mn	6.0	45.3	3.5	28.1	0.9	1.0	78.1	4.5	11.5	2.5	9.9	4.0	4.4	3.0	16.4
Mo/Mn	16.8	10.9	16.9	2.5	11.9	10.1	6.0	17.7	3.0	11.3	2.3	18.1	3.1	14.3	3.7
Fe/Pb	0.9	2.2	0.9	1.1	0.8	0.8	2.3	0.8	0.8	0.9	1.5	0.9	0.9	0.9	1.4
Zn/Pb	0.1	0.5	0.1	1.2	0.4	0.3	1.7	0.2	1.1	0.3	1.3	0.2	1.1	0.2	1.0
Cu/Pb	0.2	0.4	0.3	1.0	0.7	0.3	1.9	0.3	0.8	0.4	0.9	0.3	1.0	0.3	0.8
Cd/Pb	0.1	0.2	0.8	0.6	3.8	0.7	0.6	1.1	0.4	0.7	0.3	1.6	0.7	0.9	0.4
As/Pb	0.6	3.0	0.3	1.7	0.4	0.5	12.4	1.6	2.4	1.0	3.1	1.4	3.5	0.8	3.2
Sb/Pb	0.4	7.2	0.6	13.7	0.5	0.2	20.3	0.8	5.9	0.5	4.9	0.8	2.3	0.5	6.7
Mo/Pb	1.3	1.7	2.7	1.2	6.3	2.4	1.5	3.1	1.5	2.4	1.2	3.8	1.6	2.6	1.5
Cu/Zn	2.1	0.8	1.8	0.8	1.7	1.2	1.1	1.5	0.7	1.2	0.7	1.6	0.9	1.5	0.8
Cd/Zn	1.8	0.3	5.5	0.5	9.2	2.3	0.3	5.8	0.4	2.5	0.3	7.9	0.6	4.7	0.4
As/Zn	8.0	5.7	2.4	1.4	1.0	1.7	7.3	8.5	2.2	3.2	2.5	6.7	3.2	4.2	3.1
Sb/Zn	5.9	13.9	4.1	11.6	1.1	0.8	11.9	4.3	5.5	1.8	3.9	4.0	2.1	2.8	6.5
Mo/Zn	16.7	3.4	19.6	1.0	15.2	8.2	0.9	17.0	1.4	8.0	0.9	18.1	1.5	13.5	1.5
Cd/Cu	0.9	0.4	3.0	0.6	5.4	2.0	0.3	3.7	0.5	2.0	0.4	5.0	0.7	3.1	0.5
As/Cu	3.8	7.5	1.3	1.7	0.6	1.5	6.5	5.5	3.0	2.6	3.5	4.3	3.5	2.8	3.9
Sb/Cu	2.8	18.1	2.2	14.1	0.7	0.7	10.7	2.8	7.4	1.4	5.5	2.6	2.3	1.9	8.1
Mo/Cu	8.0	4.4	10.6	1.2	9.0	6.9	0.8	11.0	1.9	6.4	1.3	11.6	1.6	8.9	1.8
As/Cd	4.4	19.8	0.4	3.0	0.1	0.7	21.8	1.5	5.9	1.3	9.4	0.9	5.2	0.9	8.0
Sb/Cd	3.3	47.7	0.7	24.9	0.1	0.3	35.6	0.7	14.7	0.7	14.7	0.5	3.5	0.6	16.9
Mo/Cd	9.2	11.5	3.6	2.2	1.6	3.5	2.7	2.9	3.8	3.2	3.5	2.3	2.4	2.9	3.8
Sb/As	0.7	2.4	1.7	8.2	1.1	0.5	1.6	0.5	2.5	0.5	1.6	0.6	0.7	0.7	2.1
Mo/As	2.1	0.6	8.1	0.7	15.2	4.8	0.1	2.0	0.6	2.5	0.4	2.7	0.5	3.2	0.5
Sb/Mo	0.4	4.1	0.2	11.3	0.1	0.1	13.1	0.3	3.8	0.2	4.3	0.2	1.4	0.2	4.5
Пт/Пе	32.8	56.6	9.4	18.5	0.8	1.4	109.7	45.2	8.2	6.8	7.8	36.1	5.9	14.8	16.2

Notes. Types of land use areas: IN — industrial and non-residential, T — traffic, AG — agricultural, H — high-rise buildings, M — mid-rise buildings, L — low-rise buildings, R — recreational. Species: 1 — dandelion, 2 — maple. Пт — amount of toxic elements (Cd·As·Pb·Sb), Пе — amount of essential elements (Mn · Cu · Mo · Zn). Ratios marked yellow if values ⩾ 2.0 and green if values ⩽ 0.5.

Average Fe/Mn ratios in EAD maple and dandelion leaves relative to background plants were up to 3.4 and 4.8, respectively; Pb/Mn ratios were up to 2.4 and 5.5, respectively. This is due to the contravention of photosynthesis processes, when accumulation rates of essential elements, which play role in plant growth, decrease and accumulation rates of toxic elements increase (Table 3). The highest Fe/Mn (13.9 and 12.0) and Pb/Mn (6.3 and 13.3) ratios in maples and dandelions were found in industrial areas. Among maples, slightly lower values appeared in areas with high-rise buildings (Fe/Mn of 8.7, Pb/Mn of 3.9). For dandelions, Fe/Mn and Pb/Mn ratios were slightly lower in traffic areas (5.9 and 6.2, respectively) where they were exposed directly to motor-vehicle emissions.

The ratios Zn/Mn and Mo/Mn can be used to compare photosynthesis processes and plant growth. For maple leaves in the EAD, Zn/Mn was 2.6 times higher than in background samples, while in dandelions it was 1.1 times higher. This ratio varied from 2.5 for maples in mid-rise developments to 8.2 for those in industrial areas, and 36.5 for those in high-rise developments. Among dandelions, it varied from 0.8 in agricultural areas to 1.4 in low-rise developments (Table 3). Variation in Mo/Mn ratios was greater than in Zn/Mn ratios. The lowest Mo/Mn ratio in maples (2.3) occurred in low-rise developments, while the highest (10.9) was in industrial areas; the average Mo/Mn ratio for EAD maples was 3.7. Variation was greater among Mo/Mn ratios for dandelions: the lowest (10.1) occurred in high-rise developments, and the highest (18.1) was in recreational areas; the average Mo/Mn ratio for EAD dandelions was 14.3.

Differences in biogeochemical specialization among herbaceous and woody plants can be shown using the Sb/Mo ratio. In the EAD, it was 4.5 times higher for maples, and about 5 times lower for dandelions, than at the background site (Table 3). The Sb/Mo ratio for dandelions was lower than 1 at all sites. The highest values of Sb/Mo were in maples near high-rise buildings and traffic areas (13.1 and 11.3, respectively), while the lowest levels were in dandelions around high-rise buildings and in agricultural areas (0.1).

To determine the integral ratio of toxic to essential elements, the following index is suggested: (Cd·As·Sb·Pb)/(Cu·Mn·Mo·Zn). For maple leaves from the EAD, this index was 16.2 times higher than for those from the background site; for dandelions it was 14.8 times higher. Except in mid-rise developments and recreational areas, integral index levels for maples were higher than for dandelions. This indicates higher accumulation of toxic elements by maples than dandelions.

Spatial distribution of pollutants. Total-pollution indexes can be used to calculate the level of toxic chemicals in plants. There are several related approaches to pollution assessment. The C_d index was introduced by L. Hekanson to determine levels of pollution in bottom sediments. It is calculated using the equation $C_d = \sum_{i=1}^{n} EF_i$, where EF_i is the enrichment factor of *i*-pollutant in sediments, and *n* is the total number of pollutants. If $C_d < n$, the level of pollution is low; if $n \leqslant C_d < 2n$, the level is medium; if $2n \geqslant C_d < 3n$, the level is high; and if $C_d \geqslant 3n$, the level is very high [Hekanson, 1980]. The Z_c total-pollution index, introduced by Yu. Saet, is calculated using the equation $Z_c = \sum_{i=1}^{n} EF_i - (n-1), \Sigma EF_i$ — $(n$ — 1), where EF_i is the enrichment factor of *i*-pollutant in soils or snow dust, and *n* is the total number of pollutants with $EF > 1.5$ [Geochemistry..., 1990]. The grades of this index for plants have not yet been developed, which is why some scientists use grades for soils instead [Kasimov et al., 2012a]. If $Z_c < 16$, the level of pollution is low; if $16 \leqslant Z_c < 32$, the level is medium; if $32 \leqslant Z_c < 64$, the level is high; if $64 \leqslant Z_c < 128$, the level is very high; and if $Z_c \geqslant 128$, the level is extremely high.

Plants respond to environmental pollution not only with accumulation, but also with depletion of some chemical elements due to

changes in the intensity of biological processes [Bargagli, 1998; Kabata-Pendias, 2011]. As a result, O. Sorokina [2013] proposed the biogeochemical transformation equation Z_V for poplar leaves and larch needles in Ulaanbaatar City: $Z_V = \sum_{i=1}^{n1} EF_i + \sum_{j=1}^{n2} DF_j - (n_1 + n_2 - 1)$, where EF_i is the enrichment factor of *i*-element in plants, n_1 is the total number of elements with $CF > 1$, DF_j is the depletion factor of *j*-element in plants, and n_2 is the total number of elements in which $DF > 1$. The Z_V index shows disruption of normal correlations for elements in different parts of a plant according to its phylogenetic and ontogenetic specialization. This index also provides a quantitative representation of imbalances among element ratios due to anthropogenic pressure. O. Sorokina suggested that if $Z_V < 15$, the level of biogeochemical transformation is low; if $15 \leqslant Z_V < 20$, the level of biogeochemical transformation is medium; if $20 \leqslant Z_V < 25$, the level of biogeochemical transformation is higher than medium; and if $Z_V \geqslant 25$, the level of biogeochemical transformation is 2 times higher than medium. But Z_V levels may differ in various plant species. Fig. 3 shows the number of sites in the EAD with different levels of Z_V in maple and dandelion leaves. Figure analysis was used to identify new gradations of Z_V for these species (Table 4).

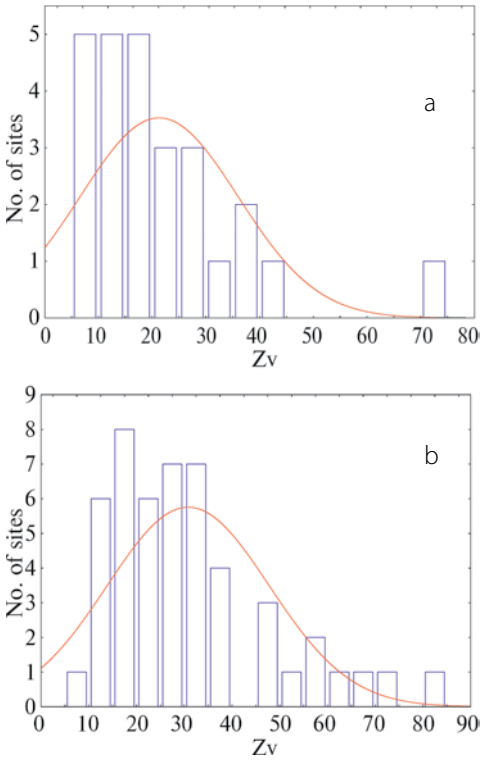

Fig. 3. Number of sites with different levels of biogeochemical transformation factor Z_V in maple (a) and dandelion (b) leaves

Table 4. Gradations of Z_V for maple and dandelion leaves from the EAD and corresponding levels of biogeochemical transformation

Values of Z_V in leaves		Biogeochemical transformation
maple	dandelion	
<15	<15	Very low
	15–25	Low
15–25	25–35	Medium
25–35	35–45	High
35–45	45–55	Very high
>45	>55	Extremely high

Fig. 4. shows the spatial distribution of Z_V in EAD maple and dandelion leaves. In recreational areas and low-rise developments there were low and medium levels of biogeochemical transformation in maple leaves. This indicates low-intensity anthropogenic impacts on plants in these areas.

High biogeochemical transformation of maple leaves was found in recreational areas as well as mid- and high-rise developments near industrial sites, major roads and railways (Fig. 4). A similar situation was found in old residential areas with low-rise buildings in the southeast EAD (sites 18 and 19). There were very high Z_V levels in maple leaves from the following areas: along Entuziastov Rd., around the high-rise buildings near Veshnyakovskaya Rd., and at the Sokolinaya Gora industrial zone in the northwest EAD. Sokolinaya Gora showed particularly intense anthropogenic impact, resulting in extremely high rates of biogeochemical transformation in maple leaves.

In most recreational areas and high-rise developments, along with some mid-rise and low-rise developments, there were

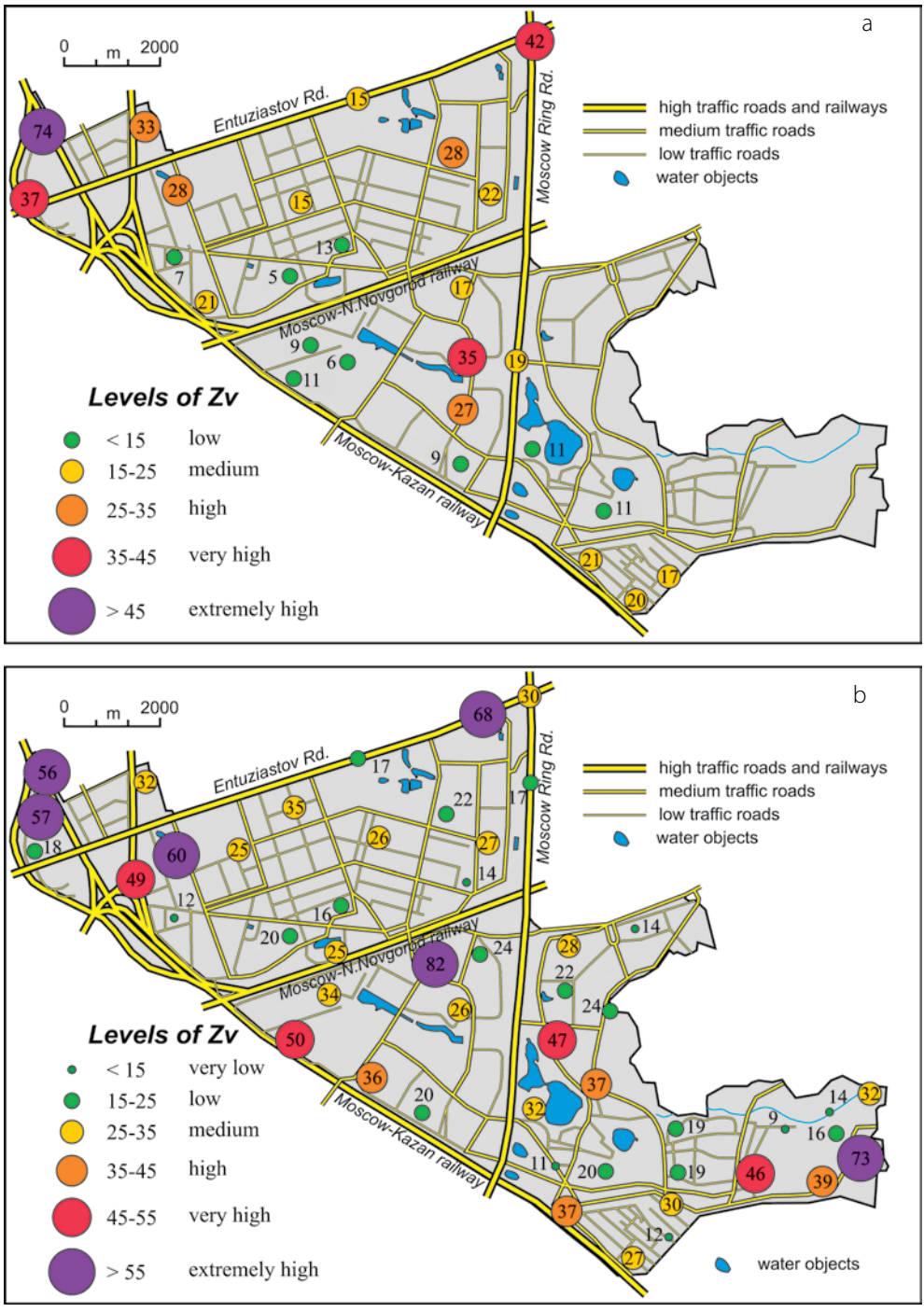

Fig. 4. Spatial distribution of biogeochemical transformation factor Z_v of maple (a) and dandelion (b) leaves in the EAD

very low and low levels of biogeochemical transformation in dandelion leaves. Medium and high Z_v levels were found in low-rise developments, some agricultural areas, recreational zones, medium-rise developments and high-rise developments. Extremely high and very high biogeochemical transformation in dandelion leaves appeared

at industrial sites near Entuziastov Rd. and the railway.

CONCLUSION

In the EAD, dandelions accumulate $Mo_{12,7}Pb_{4,9}Cd_{4,4}Fe_{4,3}As_{3,9}Sb_{2,7}Cu_{1,4}$, while maples accumulate $Sb_{9,7}As_{4,6}Mo_{2,2}Fe_{2,0}Zn_{1,5}Pb_{1,4}Cu_{1,2}$ — normalized to concentrations in background samples from an unpolluted site west from Moscow.

High Sb accumulation was a key feature among maples in each land-use area. The main difference between dandelions and maples was strong Mo accumulation in all land-use areas by herbaceous plants. Another difference between herbaceous and woody plants was higher EF levels in dandelions. This can be explained by the fact that dandelions take nutrients and microelements from the surface layer of soil, which is normally more polluted than deeper layers. Dandelions and maples do not accumulate Mn due to antagonism between Zn, Mo and Mn in soils. Copper is not concentrated by herbaceous species because of antagonism between Mo and Cu.

The highest Fe/Mn and Pb/Mn ratios were found in industrial areas for both species. The ratios Zn/Mn and Mo/Mn may also be useful for considering photosynthesis processes and plant growth. Differences in the biogeochemical specialization of herbaceous and woody plants can be shown using Sb/Mo ratios. These ratios were 4.5 times higher for urban maples and about 5 times lower for urban dandelions in the EAD than for corresponding background samples. Ratios for integral estimation of toxic and essential elements were calculated using the following index: (Cd·As·Sb·Pb)/(Cu·Mn·Mo·Zn). In all areas except mid-rise developments and recreational zones, integral index values were higher for maples than for dandelions.

A Z_v ratio was used to show the biogeochemical transformation intensity of urban plants. High and very high biogeochemical transformation for maple leaves was found in recreational areas, around mid- and high-rise buildings, near industrial sites, and along large roads and railways. There were extremely high and very high rates of biogeochemical transformation among dandelion leaves in the industrial area near Entuziastov Rd. and near the railway.

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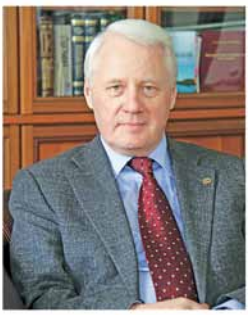

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SEASONAL MORTALITY PATTERNS DUE TO DISEASES OF THE CIRCULATORY SYSTEM IN PORTUGAL

ABSTRACT. Exposure to cold weather has negative consequences on human health. Studies have been showing that the seasonality of mortality has an evident peak during winter months in European countries. However, the highest increases in mortality are registered in countries with mild winters. According to several studies winter deaths seem to be associated with low socioeconomic conditions. The main aims of this study are to identify the trends of mortality due to diseases of the circulatory system and excess winter deaths in Portugal and to assess the geographical pattern of seasonal mortality. In the 20 years under analyses, mortality due to diseases of the circulatory system increased 38% during winter months when compared to the non-winter period. Important regional disparities were found, the Excess Winter Death index ranged from 21% to 48%, the central regions tend to have better results. Our results indicate that although circulatory mortality is significantly decreasing in Portugal, the vulnerability to seasonal cold weather remains as an important public health issue. These findings suggest that the exposure to cold weather is an important determinant of cardiovascular diseases that is still neglected in Portugal.

KEY WORDS: diseases of the circulatory system; seasonal mortality; excess winter deaths; Portugal

INTRODUCTION

In Portugal, mortality due to diseases of the circulatory system is decreasing at an important pace since the last decades in result of significant improvements in healthcare and life conditions [Santana, 2014]. However, still remains as one of the main causes of morbidity and death.

In most European countries, mortality has an important seasonal variation, characterized by a peak during the winter months and a decrease in rest of the year [Healy, 2003], this pattern is even more significant when the analysis is focus on diseases of the circulatory or respiratory system [Eurowinter Group, 1997; Rau, 2006]. Cardiovascular mortality is strongly related with weather conditions, being the cause of death with higher increases due to temperature variations. The increases are recorded both during high and low temperatures, although the number of Excess Winter Deaths (EWD) is higher than the heat related mortality.

Exposure to lower temperatures has important biological effects. Within certain thresholds, the human body can maintain thermal comfort through appropriate thermoregulatory responses so that physical and mental activities can be pursued without

any detriment to health [Xu et al., 2012]. However, when the human body is exposed to temperatures below the biological optimum the circulatory system becomes under stress, causing an increase in blood pressure, blood viscosity and fibrinogen concentration [Keatinge, 2002; Maheswaran et al., 2004; Stocks et al., 2004].

Healy [2003], mentions the "paradox of excess winter mortality", as the higher mortality rates are generally found countries with milder winter where, all else equal, there should be less potential for cold strain and cold related mortality. This pattern suggest that excess winter mortality should not be seen as an environmental inevitability [Davie et al., 2007]. Besides the meteorological conditions, several factors influence the vulnerability to cold weather: physical activity, age, gender and accompanying exercise [Stocks et al., 2004], as well as the ability to avoid cold exposure in indoor and outdoor environments [Mäkinen et al., 2006; Rau, 2006; Vasconcelos et al., 2011].

Thus, excess winter mortality should be seen as an important public health issue that demands proper measures and policies [Monteiro et al., 2012]. In some countries, such as Scotland and United Kingdom, EWD are seen as a public health priority [Gemmell, 2001], and specific actions to mitigate it are supported. Reduction of fuel poverty, monitoring and subsidizing the vulnerable homes are some examples of the national initiatives developed at a national level.

Unlike other countries, in Portugal seasonal mortality and morbidity is underrated as a severe threat to public health, there is no systematic quantification or measures to tackle the vulnerability to cold weather.

This paper aims to: i) characterize the evolution of overall and seasonal mortality due to diseases of the circulatory system in Portugal (since 1990 until 2009); and ii) identify the geographical pattern of excess winter mortality (in the ten years period 2000-09).

DATA AND METHODS

This study uses Standardized Deaths Rates due to diseases of circulatory system, obtained from the European Health for All database (http://data.euro.who.int/hfadb/), and monthly deaths through diseases of the circulatory system (ICD 10: I00-I99), obtained from Statistics Portugal (www.ine.pt). Data was collected from 1990 until 2009. Deaths by month were standardized to 30-days with an adjustment for leap years, and analysed by NUT III.

The number of EWD and the EWD index were calculated according to Johnson and Griffi [2003] in order to quantify the winter mortality burden.

The number of EWD is calculated by comparing the number of deaths in winter months (December to March) with the average number in non-winter months (the previous August to November and the following April to July):

$$EWD = \text{Winter deaths} - \frac{\text{Non-Winter death}}{2}.$$

Once the number of EWD was found, the EWD rate was calculated in Portugal (from 1990 to 2009) and each NUT III (ten years period 2000-09) using the resident population available in Statistics Portugal.

The seasonal impact of winter was assessed through the EWD Index. It indicates whether there are higher than expected deaths in the winter compared to the rest of the year:

$$EWD\text{index} = \left(2\frac{\text{Winter deaths}}{\text{Non-winter deaths}} - 1\right)100.$$

And their 95% confidence intervals:

$$CI = 2e^{\left[LN\left(\frac{\text{Winter deaths}}{\text{Non-Winter deaths}} \pm 1{,}96\sqrt{\frac{1}{\text{Winterdeaths}} + \frac{1}{\text{Non-Winter deaths}}}\right)\right]} - 1.$$

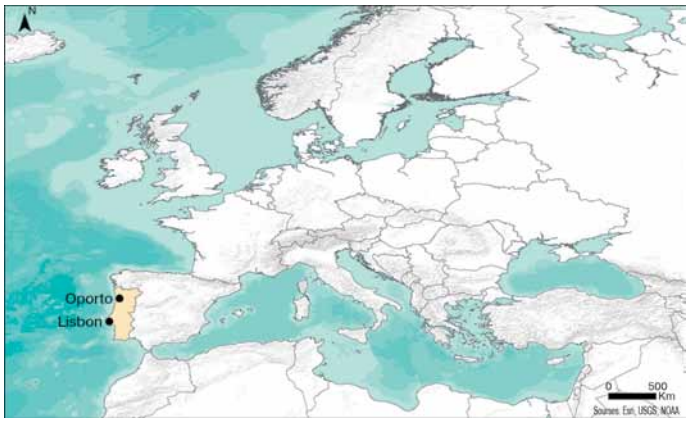

Fig. 1. Location of the study area. Portugal.

The joinpoint regression model was used to identify significant changes cardiovascular mortality, EWD rate and EWD index. This method detects statistically significant changes in trend, and the annual percent of change is computed by each of those trends by means of generalised linear models assuming a Poisson distribution [Fernandez et al., 2001]. The joinpoint analyses were performed using the "Joinpoint" software from the US National Cancer Institute (available at http://surveillance.cancer.gov/joinpoint/).

RESULTS

Portugal is located by the Atlantic Ocean (Fig. 1), according to Köppene and Geiger the southern regions are classified as a hot-summer Mediterranean climate (Csa) and the northern as warm-summer Mediterranean climate (Csb), both with mild winters [Vasconcelos et al., 2011].

TREND ANALYSIS

Since 1990, a decline in the standardized death rate due to diseases of the circulatory system has been observed. Two points, where the rate changes significantly, were found and three periods with significant decreases ($p < 0.05$) were identified: 1991-03; 2003-06; 2006-09.The second period (2003-06) had the higher decreasing rate (annual percent change of 7.95%) (Fig. 2).

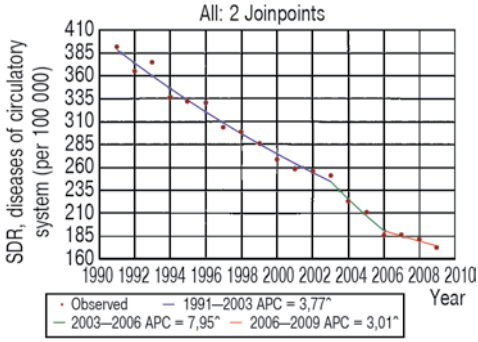

Fig. 2. Trends in Standardized Death Rates due to diseases of circulatory system, all ages, per 100 000 inhabitants.

By analyzing the monthly distribution of the number of deaths due to diseases of the circulatory system an important seasonal pattern was identified. The winter months (from December to March) have the highest number of deaths. January is the month with higher proportion of deaths (11.5%) while September had the lowest 6.5% (Fig. 3).

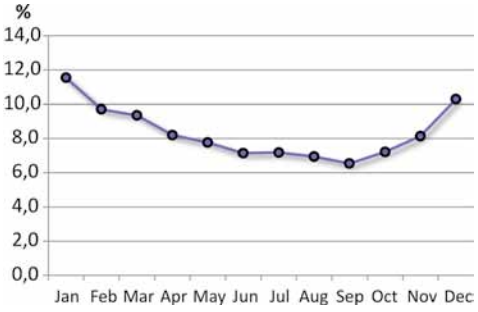

Fig. 3. Monthly distribution of deaths due to diseases of circulatory system (%) (1991–2009)

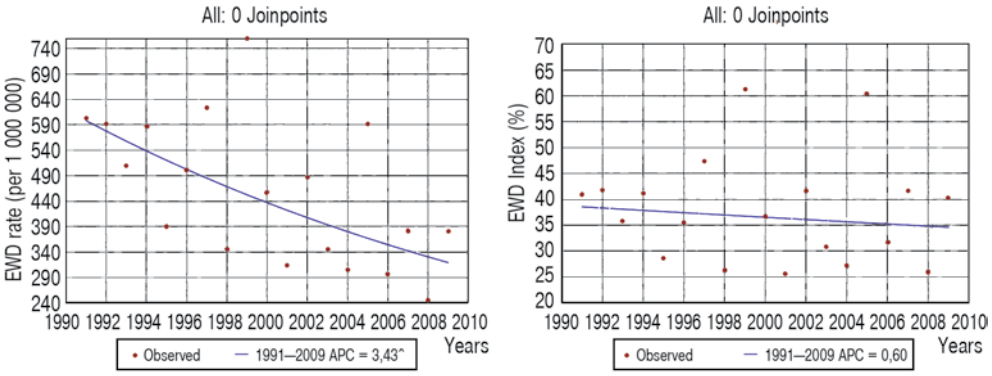

Fig. 4. Trends of Excess Winter Death rate (A) and index (B) due to diseases of circulatory system

The EWD rate is significantly decreasing since 1990 with an annual percent change of 3.43% ($p < 0.05$), however this trend is not constant due to important inter-annual variations. The highest values were recorded between 1999 with 749 per 1.000.000 inhabitants (Fig. 4 A).

The EWD index is not decreasing significantly; the evolution in the 20 years under analysis is marked by the inter-annual fluctuations. The highest value was recorded in 1999 when the number of deaths in winter months was 61.3% higher than the number of death recorded in the rest of the year (Fig. 4 B).

GEOGRAPHICAL PATTERN

Winter mortality increases were recorded throughout the country, although, the seasonal burden varied remarkably across regions. The EWD rate through circulatory diseases varied from 249 to 742 deaths per million inhabitants, while the country average is 378 per million inhabitants, the worst results were in the inland and southern regions, while the best were recorded at the coastal areas (Fig. 5).

The EWD index country average is 40%, but important regional disparities were found (ranging from 21% to 48%), the central regions of the country tend to have better results, even though a clear pattern was not identified. During winter-moths the number of deaths was 40% higher than in non-winter months, two regions had significantly lower EWM index than the Portuguese average and any region had significantly higher values.

DISCUSSION

Joinpoint analyses allowed the identification of significant decreasing trends, between 1990 and 2009, in the standardized death rates due to diseases of the circulatory system and EWD rate. Despite these trends, the EWD index is not decreasing significantly. The geographical pattern shows important regional disparities, the EWD rate tend to be higher in the regions near the border and the EWD index is lower in the central regions, although is difficult to identify a clear pattern.

The improvements in healthcare and living conditions can explain the significant decrease in the standardized death rate due to diseases of the circulatory system. These diseases have been the major cause of death in Europe for some decades and therefore several European countries have undertaken health policies to control this public health burden [Levi et al., 2002]. The gap between Portugal and the other European countries is diminishing but still has higher mortality rate than the EU' 15 average [Santana, 2014].

There is an uneven distribution of mortality throughout the year in Portugal, the mortality seasonal pattern shows a clear cluster during winter months, this trend is usually found in several European countries [Rau, 2006], and

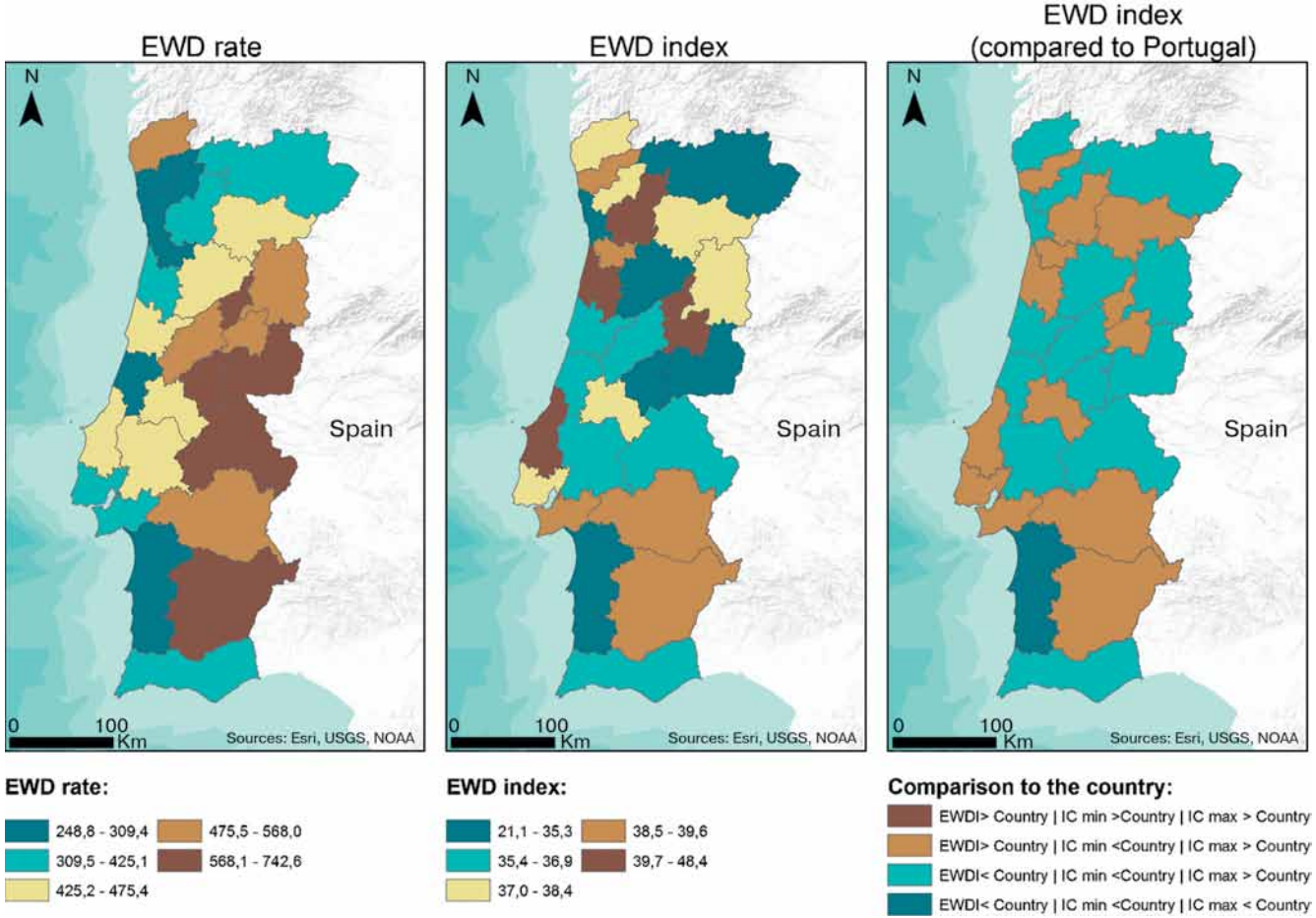

Fig. 5. Excess Winter Death rate, index and comparison with country average

Portugal is often described as the European country with higher vulnerability to cold weather [Healy, 2003; Almendra, Freira, Vasconcelos, 2012; Eurowinter Group, 1997].

The excess winter deaths are associated with several environmental factors such as exposure to cold weather [Burkart et al., 2011; Vasconcelos et al., 2013], but biological (e.g., age and sex) [Goodwin, 2000], socio-economic (e.g., deprivation, housing conditions) [Maheswaran et al., 2004; Healy, 2003; Vasconcelos et al., 2011] and behavioural (e.g., use of adequate clothing, avoiding the exposure to cold weather) [Aylin et al., 2001; Mäkinen et al., 2006; Rau, 2006] factors also play an important role in the vulnerability to cold weather.

Inter-annual variations are usually explained by winter characteristics (eg. temperature, extend) and influenza incidence rates, these events can contribute to abnormal values of EWD rate and index and explain outliers.

Different regional patterns were found between the EWD rate and index, in order to understand them is important to acknowledge that temperature and thermal comfort are two very different parameters, being the last more important to explain the winter mortality increase. This disparity between patterns was also found among regions in England [Office for National Statistics, 2013].

The EWD rate geography is consistent with the overall mortality pattern, and so is strongly influenced by biological and life style determinants such as age, obesity, sex, smoking, alcohol consumption, sedentary habits, stress, diet, among others [Dahlöf, 2010].

The EWD index geographical pattern is more difficult to explain, neither age, deprivation nor the overall mortality due to diseases of the circulatory system can fully explain it. Further studies focus on behaviour conditions are needed in order to understand this pattern.

The EWD rate compares the number of deaths in winter months with the average number of deaths occurring in non-winter months. This measure is important to quantify the burden of excess winter deaths, but fails when comparisons between sexes, age groups and regions are needed once is strongly related with the overall mortality due to diseases of the circulatory system and their determinants (e.g., Age). The EWD index allows comparisons between different geographies or age groups once it is calculated as the number of excess winter deaths divided by the average non-winter deaths [Johnson, Griffi, 2003].

With the improvements in socioeconomic and healthcare conditions it would be expected to assist a significant decrease in both EWD rate and index. Although the decreasing trend observed in the standardized death rate was followed by the EWD rate there is no significant trend in the EWD index. In England (since 1991), the EWD index does not have a significant decreasing trend either [Office for National Statistics, 2013].

CONCLUSIONS

These findings highlight that although significant efforts have been developed to reduce the impacts of cardiovascular diseases in Portugal, their effects on the disease seasonality are still far from being achieved. One possible explanation is that other epidemiology aspects of the cardiovascular diseases need to be addressed, such as the indoor environment and the reduction of cold exposure.

Nevertheless, the seasonal pattern in the mortality by circulatory system diseases is highly evident and it is still not properly addressed by health authorities in Portugal.

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GEOGRAPHIC INFORMATION SYSTEMS AND COASTAL PLANNING IN AUSTRALIA

ABSTRACT. The objective of this paper is to demonstrate the ability of visualization and simulation techniques to aid and simulate current and future directions in coastal planning. The process of visualization will interrogate the coastal cities of Portland, Apollo Bay, Anglesea and Hobsons Bay in south-eastern Australian coastal seaboard through a progression of projections and simulated forecasts from 2014 to 2050 to see if a process(s) or methodology could help in planning the future growth of coastal settlements. The analysis uses Geographic Information Systems (GIS) associated with planning application software.

KEY WORDS: simulation techniques, visualization techniques, coastal planning, sustainable growth, coastal settlements

INTRODUCTION

Over the past few decades coastal cities around the world have grown at an incredible rate. With this growth have come major challenges relating to land use planning, social relationships, economic development, bio-diversity and the degradation of the ecological footprint. Three forces are working to influence the growth rate of coastal cities. They include: population growth (i.e. the type and quantity of human demand for land); the existing and future properties of the land (i.e. current land status or changes due to nature and human activities); and, finally technical changes of a land system (i.e. zoning or the influence of other external factors).

Coastal cities have long been susceptible to processes of change. Different cities have taken very different approaches to these developments, with some realizing the unprecedented opportunity for revitalization of depressed yet extremely valuable land/property. Others, through necessity or short sightedness, have chosen to remove funding from these areas further exacerbating the problem.

Sassen [2001] has observed that "Since the 1980s the weight of economic activity in coastal cities has shifted from production to finance and highly specialized services". Similarly, Van der Knapp & Pinder [1992] have also concluded that "historically the relationship between cities their coasts and ports has been interwoven, both physically and economically. However, this long-established symbiosis was broken during the 20th century with cities becoming more multifunctional and subsequently reducing their dependence on the ports, where traditional relationships between cities their coasts and ports were further weakened by structural economic changes". Thus, "the evolution of maritime technology, movement of coastal activities and coastal

closures were also associated with the decline of traditional industry, especially in relation to docklands" [Hoyle 1988], and thus "waterfront regeneration was seen, to some extent, as an urban panacea, a cure-all for ailing cities searching for a new self-image or way to compete for capital development or tourism" [Marshall 2001].

The 20th century shows drivers for coastal city regeneration as being

- the reduction in many industrial activities and subsequent need to adapt to a changing use of the area;
- a need to use derelict buildings as high quality residential zones; and
- the reintegration of industrial zones back into the city.

Accordingly, how can we undertake modelling of future growth scenarios that adequately and accurately incorporates climate change and population growth scenarios to better aid our land use strategies and planning policies. While normative thinking historically involved estimate-informed scenarios, and more recent GIS modelling has offered some scope for appreciating the scenarios and impacts, both are limited by the complexity and volume of information, and the accuracy of the information at hand. Complexity and volume, while ideal for GIS modelling, is only as good as the number of variables incorporated and the quality and accuracy of the data imputed.

Therefore, this paper addresses: To efficiently plan for future urban growth you must undertake a two-step process. Step one is to disaggregate demographic and social economic information. Step two is to combine this with environmental, infrastructure and forecast data within land use models. And, as a consequence, can visualization techniques portray information so that it is legible, easy to understand and thus more likely to be used by practitioners?

This paper offers a model for a more detailed investigation of the research question, drawing upon 4 south-eastern Australian coastal cities that are already experiencing climate change and population growth impacts, that additionally incorporates the tool of urban design as a frame to better consider growth and its consequences upon the physical, environmental and infrastructure landscape of each city.

SUSTAINABILITY

What constitutes sustainability and sustainable development? For the purpose of this discussion sustainability can be defined as "a multidimensional and multi-level approach to creating future oriented way of living that balances human activity and wildlife processes over long term time frames. The New South Wales government has defined sustainability as "living within the limits of what the environment can provide, the equal distribution of resources and opportunities". [New South Wales 2014].

The concept of sustainability development is based on three pillars: economic, social and environmental sustainability. The effects of urban patterns on the ecosystem using the concepts of the three pillars has been examined by several researchers including, Alberti [2005], Amir & Gidalizon [1990], Brunckhorst [2005], Buhmann [2003], Byrd [2011], Curtis [2010], Farr [2007] and Girardet [1999]. Our research mirrors the three pillars concepts as it examines the impact of development at the personal, economic and environmental level. The concept of sustainable development is now commonplace in the planning process

The topic of sustainable development, its evaluation and their respective tools are the centre piece of this research. A number of researchers [Amir & Gidalizon, 1990; Rees & Wackernagel, 1996; Satterthwaite, 1997; Morse, McNamara *et al.,* 2001; Becker, 2004; Alberti, 2005; Brunckhorst, 2005; Robinson, Carmichael *et al.,* 2006; Wallis 2006; Ness, Urbel-Piirsalu *et al.,* 2007; Wallis, Richards *et al.*,

2007; Graymore, Sipe *et al*., 2009; Arciniegas, 2012; Garschagen & Romero-Lanko, 2013] have looked at the effect urban patterns have had on the concept of sustainability and sustainable development.

Planning has been defined as "a conceptual system" [Chadwick 1971]. Today's land systems are complex natural economic systems consisting of environmental, economic and social factors.

The traditional approach to the Land Use Planning Process is expressed in Fig. 1 that involves:

- The establishment of goal;
- The formulation of what needs to be resolved (i.e. the problem);
- A selection of courses of action (i.e. scenarios);
- Evaluation of the scenarios;
- Selection of a course of action;
- Implementation of an action plan to resolve the problem;
- Review of the implementation of the action plan; and

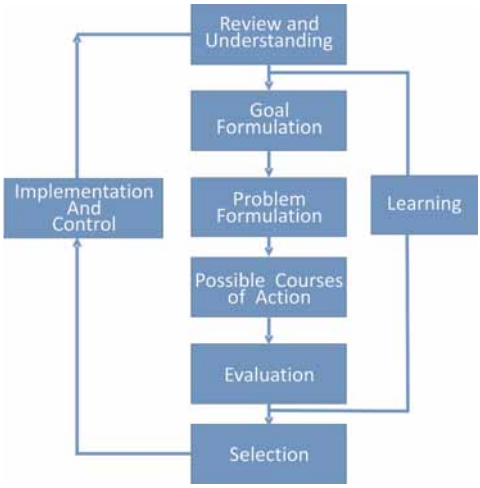


Fig. 1. The Planning Process.
Source: [Reif, 2013].

- Modification of the plan if required to meet the goals of the project.

This type of framework represents a traditional normative model where the planner sets up a set of goals and from these develops measurable objectives.

The use of scenarios in land use planning is well documented [Wollenberg, Edumnds et al., 2000; Tress & Tress, 2003; Dockerty, Appleton et al., 2006; Verburg, Schulp et al., 2006; Shaw, Sheppard et al., 2009; Varum & Melo, 2010: and Schroth, 2014]. The question facing today's town planner is how to better understand the complexities and variables that comprise the land use planning discipline. Modelling provides one method to better understand the complexities and variables to gain a greater insight into how the various factors are interrelated. There are many forms of land use planning models including: GIS based models; Econometric type integrated models; Simulation integrated models; Dynamic simulation models; Integrated land use/transportation models; and Global level simulation models.

Models can be classified according to three basic purposes:

1. Descriptive models that categorize and relate much about the inner workings of the urban environment that affect its structure;

2. Projection models involving relationships between variables; and

Normative models where the planner sets up a series of goals and from these goals develop a series of measurable objectives

Land use models (see Fig. 2) can represent a range of topics including: Land classification; Land structure and analysis; Land evaluation; Land potential productivity; Land carrying capacity; and Demand forecasting.

The development of Geographic Information Systems (GIS) has added to the development

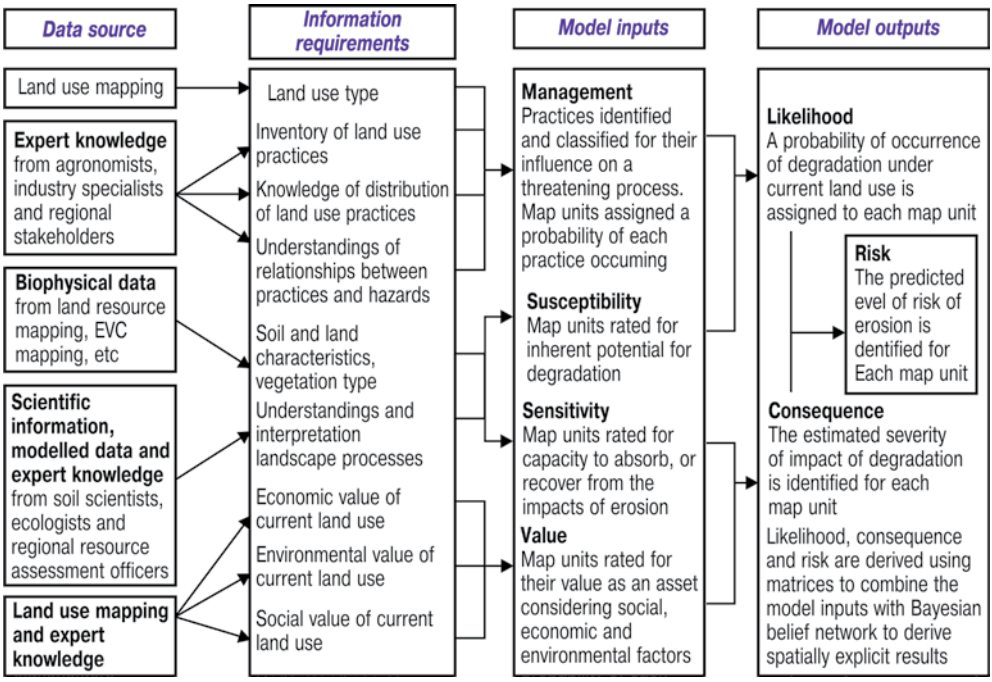


Fig. 2. A theoretical model highlighting the components in a land use planning model

Source: [Victoria, Department of Primary Industry, 2007].

of land use models and opened new horizons for the management and manipulation of spatial data sets. There are four types of GIS analytical approaches to spatial analysis and modelling. They include:

- Rules Based Spatial Analysis;
- Knowledge Based Spatial Analysis;
- Interactive Spatial Analysis Method; and
- Geographic Spatial Analysis

McHarg [1969] has explained that "of the four approaches, rule-based modelling is perhaps the most widely used GIS-based approach in the form of map overlay analysis which has many applications in planning contexts. Data pertaining to several attributes of a study area (elevation, slope, climate, hydrology, land uses) are stored in layers in a GIS. Different layers are overlain to generate maps showing "unique conditions"". Unwin [1996] has also observed that "overlay analysis is used also to predict a new map as a function of the distribution of observed attributes". The four approaches were collectively used in this research providing the ability for the data to be visualized in either 2D or 3D which aided in its interpretation.

Data visualization is not a new phenomenon (Fig. 3). Few [2007] has concluded that "data visualization dates back to the 2nd century AD. The earliest table that has been preserved was created in the 2nd century in Egypt to organize astronomical information as a tool for navigation. A table is primarily a textual representation of data, but it uses the visual attributes of alignment, white space, and at times rules (vertical or horizontal lines) to arrange data into columns and rows. Tables, along with graphs and diagrams, all fall into the class of data representations called charts".

In the 17th century Rene Descartes, the French philosopher and mathematician, invented the visual representation of quantitative data in relation to two-dimensional co-ordinate scales. Two individuals in the 1970s and 1980s wrote ground breaking works relating

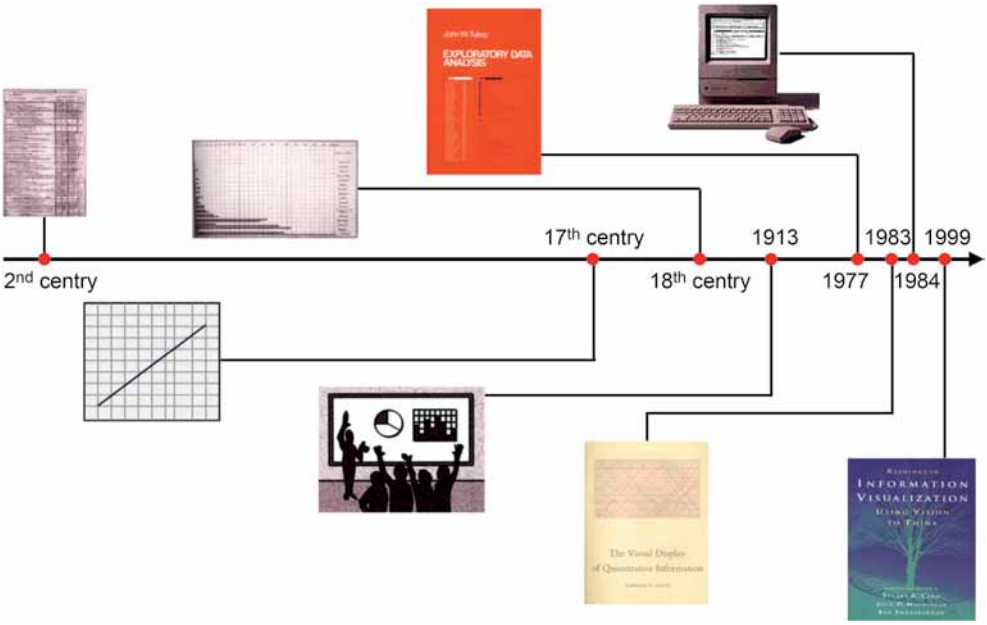


Fig. 3. History of data visualization timeline.

Source: [Few, 2007].

to data visualization as a means of exploring and understanding the complexities of data issues. One was Tukey of Princeton, who in 1977 developed a predominantly visual approach to exploring and analysing data called *exploratory data analysis*. The second was Tufte who published a ground-breaking book *The Visual Display of Quantitative Information* [1983] "which showed that there were effective ways of displaying data visually and then there were the ways that most of us were doing it, which were sadly lacking in effectiveness" [Few 2007].

Friedman [2008] has explained that the "main goal of data visualization is to communicate information clearly and effectively through graphical means". Visualizing large amounts of information interactively is one of the most attractive and useful capabilities of GIS. "Visualization of geographical information has been termed "geo-visualization"" [Thurston 2001].

The role landscape visualisation and its impact on land use planning [Zube, Simcox et al., 1987; Bishop, 1994, 2013; Davis & Keller, 1997; Al-Kodmany, 2001; Appleton & Lovett, 2003, 2005; Dockerty, Lovett et al., 2005; Andreinko, Andrienko et al., 2007; Salter, Campbell et al., 2009; Pettit, Raymond et al., 2011; Berry, Higgs et al., 2012; Bishop, Pettit et al., 2012; Aurambout, Sheth et al., 2013; Berry, Higgs et al., 2012; Lovett, 2014] has been applied in Australia and various other parts of the world. For GIS to be an effective visualization tool a GIS has to perform several functions including putting complex images into the minds of the viewers. Visualization of data assists in understanding the urban design process which is a crucial element in the geodesign/urban development process.

To define "urban design", the Urban Design Alliance defines it as: "Urban Design is the art of making places for people. It includes the way places work and matters such as community safety, as well as how they look. It concerns the connections between people and places, movement and urban form, nature and the built fabric, and the processes for ensuring successful villages, towns and cities".

Urban Design has eight Objectives:

1. Developing and insuring character – A place with its own identity;

2. Establishing continuity and enclosure – A place where public and private spaces are clearly distinguished;

3. Establishing the quality of the public realm – A place with attractive and successful outdoor areas;

4. Solidification of the ease of movement – A placed that is easy to get to and move through;

5. Strategic legibility – A place that has a clear image and is easy to understand;

6. Supporting adaptability – A placed that can change easily;

7. Ensuring diversity – A place with variety and choice; and

8. Encouraging sustainability – A placed that meets the needs of today without compromising the future.

The structural components of an Urban Design Framework are shown in Fig. 4.

Cities throughout the world have used GIS and its visualization and urban design capabilities for determining the capability to accommodate additional growth. A list of recent applications includes the cities of Auckland (New Zealand), Charleston (South Carolina, USA); Madrid (Spain), Adelaide (Australia), North Vancouver (Canada), and Reykjavik (Iceland).

CASE STUDY LOCATIONS

To test and validate the study research statement a case study approach was used to analyze and visualize for the future growth of Portland, Apollo Bay, Anglesea and Hobsons Bay. The four communities represent a rural industrial/agricultural/service community (Portland; population 10,000); a regional agricultural/retirement/tourism centre (Apollo Bay; population 2,500); a peri-urban center that is a commuter suburb to the regional city of Geelong (Anglesea; population 2,500) and a coastal city (Hobsons Bay; population 90,000) in metropolitan Melbourne, all in the state of Victoria in Australia. The location of the four communities is shown in Fig. 5.

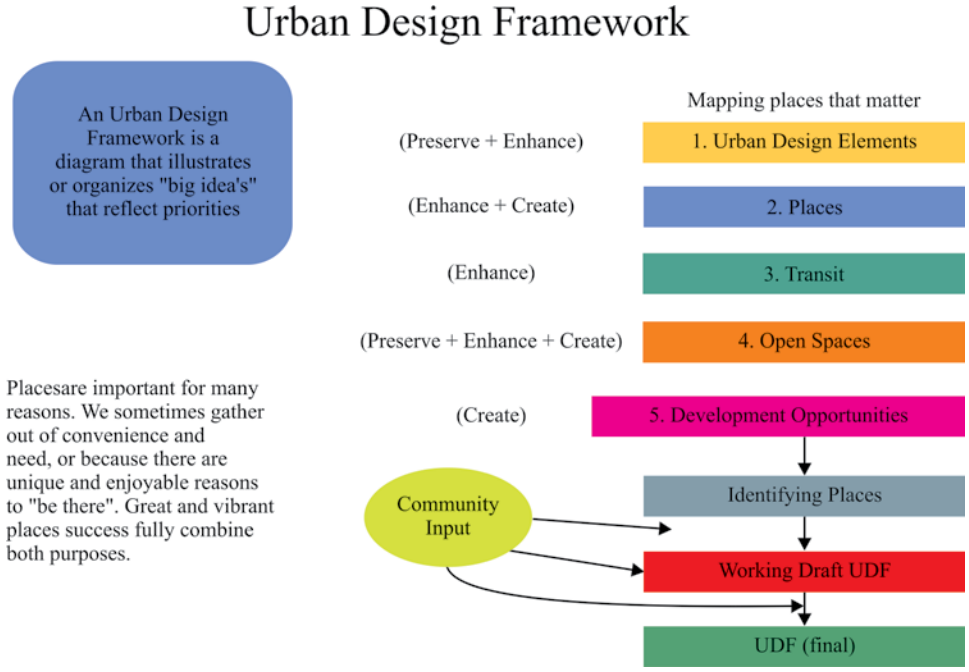


Fig. 4. Urban Design Framework.

Source: [Herron, 2012].

Fig. 5. Location of the Four Test Sites.

Source: [Herron, 2014].

RESEARCH METHODOLOGY, SOFTWARE AND DATA

The study methodology used for the research is based on the concept of scenario planning, that focuses on the use of scenarios; Landscape visualization; Sustainable development evaluations; Multi-criteria analysis; Categorization of tools for sustainability analysis; and, Spatial models through the use of Geographical Information Systems (GIS) (see Fig. 6).

Walker [2011] observes that "for the purpose of this discussion the term scenario is defined as an alternative plan that is being considered". Therefore, three scenarios have been developed for this research a low scenario equating to 90% of the Victorian government predicted population and housing growth forecast to 2050, a base scenario that is the actual Victorian government forecast, and a high scenario which is 110% of the of the Victorian government population and housing forecast to 2050. The key element is the growth in the number of houses per five-year period. The growth is what generates all of the sustainable indicators.

The use of indicators is crucial because they represent a measure of comparable success of each scenario that is developed. The primary goal of scenario planning is to correctly rank scenarios by each indicator score. The methodology for this research

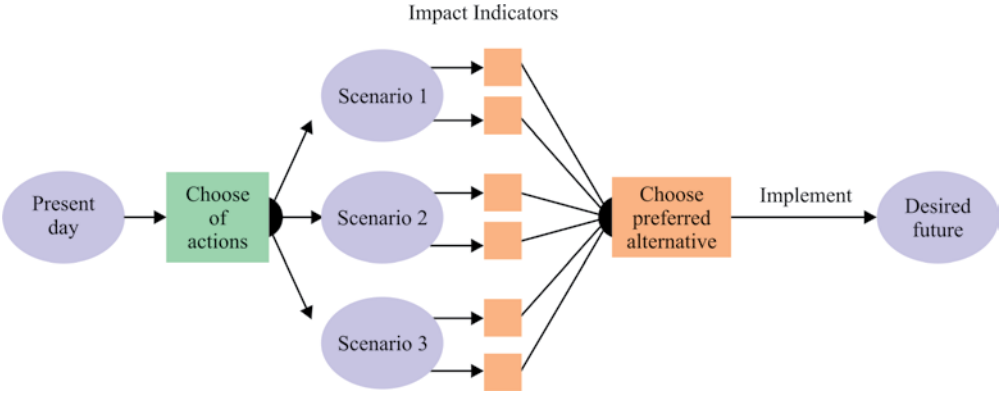


Fig. 6. Scenario planning in the decision making process.

Source: [Walker, 2011].

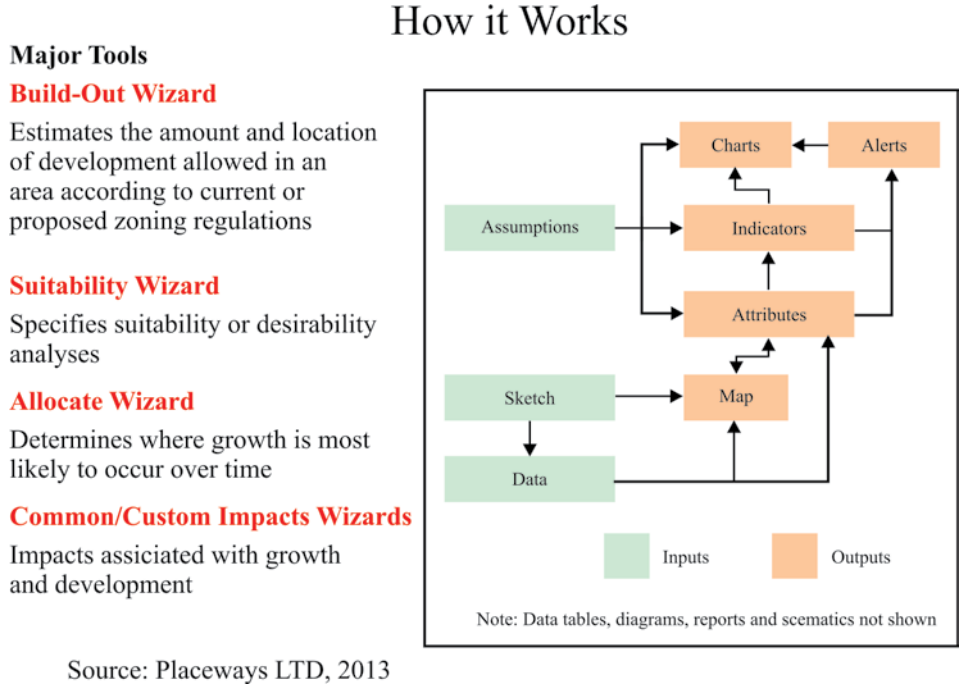


Fig. 7. Community Viz: how it works.

consisted of four procedures as highlighted in Fig. 7. A build-out analysis was performed on the four communities (Portland, Apollo Bay, Anglesea and Hobsons Bay). The build-out analysis depicts the residential, industrial and commercial potential from 2016 through 2050.

Community Viz is a planning and simulation software package. To develop economic, demographic and planning scenarios the software performs four functions including: the estimation, amount and location of new development allowed in an area according to current or proposed zoning regulations; the suitability of the new development to an area; the allocation of where growth is most likely to occur over a specific time span and finally the development of a series of environmental indicators showing the impact of the new development on the landscape.

The suitability analysis was performed on the respective build out results for each city with criteria used in the suitability analysis including:

- Proximity to the city centre;
- Sewer access;
- Proximity to hazardous areas; and
- Shoreline access

The next analysis stage was the allocate procedure which takes the results from the build out and suitability analysis and allocates the demand for buildings across the available supply of potential building locations.

Through the impact function in Community Viz over 50 indicators were developed showing the impact of development over time on the urban landscape (Table 1). The indicators included:

- Distance functions from new developments, i.e. to amenities, parks, schools, etc.;
- Environmental impacts from new development, i.e. CO^2 emissions,

Table 1. Indicators showing the Impact of Climate Change/Global Warming and Population Growth on Anglesea 2016–20

Indicator	units	Indicator	units
Common Impacts – Annual CO Auto Emissions	lbs	Common Impacts – Commercial Jobs to Housing Ratio	commercial jobs/dwelling unit
Common Impacts – Annual CO^2 Auto Emissions	tons	Common Impacts – Labour Force	workers
Common Impacts – Annual Hydrocarbon Auto Emissions	lbs	Common Impacts – Population	persons
Common Impacts – Annual NOx Auto Emissions	lbs	Common Impacts – Residential Dwelling Units	dwelling units
Common Impacts – Commercial Energy Use	million BTU/year	Common Impacts – Residential Energy Use	million BTU/year
Common Impacts – Commercial Floor Area	sq metres	Common Impacts – Residential Water Use	gallons/year
Common Impacts – Commercial Jobs	commercial jobs	Common Impacts – School Children	school children
Common Impacts – Vehicle Trips per Day			

Source: [Walker, 2011].

floodplain percentage, hydrocarbon emissions, residential water and energy usage, waste water generation, etc.;

- Land use characteristics including agricultural, commercial, industrial, open space percent, type of residential density, etc.;
- Transportation characteristics including; jobs, new transport, street density, bicycle coverage, etc.; and
- Recreation characteristics including park and recreation percentage, housing near schools, etc.

The indicators generated in the Community Viz software are based on international sources including:

- Commercial energy usage: the US Commercial Building, Energy Consumption Survey 2003; Energy Information Administration, Office of Energy Markets & End Use;
- Annual Household Energy Use: US Energy Information Administration; Auto Emissions, US EPA 2008;
- Daily Water Usage: residential water use trends in North America journal *AWWA* 1003: 2 Feb. 2011.

Australia has yet to provide a complete list of input data which could be used as information resources relating to the default assumption values in the common impact analysis. The common impacts decision tool uses formulas and default settings that are intended to serve only as a starting point for further analysis. The impact displayed may not pertain to or describe local conditions.

CASE CITIES: PORTLAND

The City of Portland (Fig. 8) is located in the south-western region of the Australian state of Victoria approximately 360 kilometres west from Melbourne. Portland is the major residential and commercial centre for Glenelg Shire, hosts approximately 10,000 people, and is the oldest place of European settlement in Victoria being founded in 1815.

Facing economic and natural sustainability deterioration, Portland is one of the most vulnerable communities in Victoria. Portland's

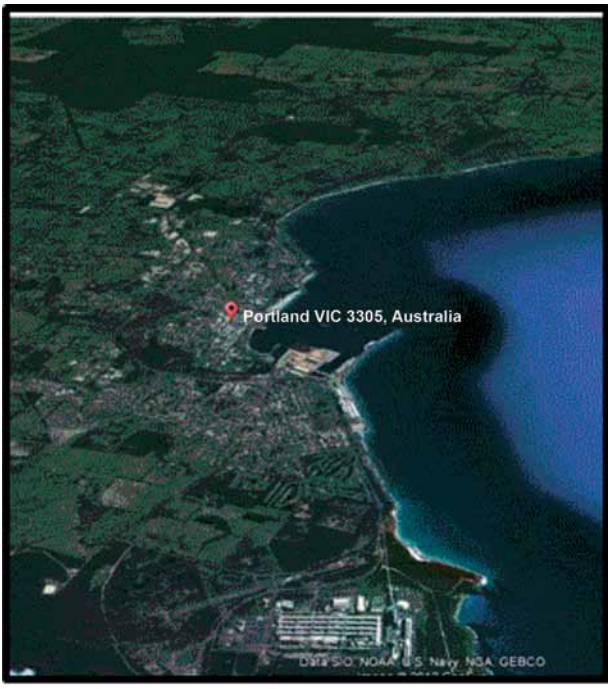


Fig. 8. Aerial Photo of Portland, Victoria.
Source: [Google Earth, 2014].

number one employer is the Alcoa smelter employing 700 staff and contributing 15% of the export GDP for the state Victoria. The smelter has electricity contracts with the Victorian government until 2025. Portland is a large producer of CO^2 emissions that are the result of the Alcoa smelter that consumes 25% of all electricity generated in Victoria all of which is generated through the burning of brown coal. Portland is also home

Table 2. Portland Simulation Data
Low/Base/High Scenarios

	2016	2021	2026	2031	2036	2041	2046	2050
Scenario 1 Low Population	10,702	11,104	11,489	11,852	13,037	14,341	15,775	17,353
Total Dwelling	4,909	5,094	5,270	5,437	5,980	6,578	7,236	7,960
New Dwelling Units	13	198	374	541	1,084	1,682	2,340	3,064
Scenario 2 Average Population	11,891	12,338	12,766	13,169	14,486	15,934	17,528	19,281
Total Dwelling	5,455	5,600	5,856	6,041	6,645	7,309	8,040	8,844
New Dwelling Units	559	764	960	1,145	1,749	2,413	3,144	3,948
Scenario 3 High Population	13,080	13,572	14,043	14,486	15,934	17,528	19,281	21,209
Total Dwelling	6,000	6,226	6,442	6,645	7,309	8,040	8,844	9,729
New Dwelling Units	1,104	1,330	1,546	1,749	2,413	3,144	3,948	4,833

Source: [Herron, 2012].

to the "green triangle" or the second largest sustainable forestry plantation in Australia, and this industry was severely impacted economically by the recent Japanese earthquakes and corresponding nuclear events of 2010–2011. The entire forestry harvest was destined for the Japanese pulp and paper industry over a 20 year period. This "green triangle" processing industry is wholly based in the area most affected by the tsunami and subsequent nuclear power plant disaster, and the industry has no immediate short or medium term date for the recommencement of pulp and paper production.

Demography

With a population of 10,000 people, Portland has a current population density of 290 km^2. The city has an area of 34.48 km^2 in size comprising 7,029 parcels or lots (i.e. residential, commercial and industrial) that host 7,029 buildings of which 4,053 are private dwellings. The amount of land dedicated to open space in Portland (i.e. parkland municipal and state parks, gardens and reserves and sporting reserves) is only 229.78 ha or 0.0229 ha per resident. Portland has a transportation system that includes a local and interstate bus network, and a regional air service to Melbourne.

The 2010 Census stated that Portland had 4,443 full time employed residents working in 20 employment categories. The top 4 industry sectors are manufacturing with 925 respondents (20.8%) followed by health care and social assistance with 563 respondents (12.6%), retail with 486 respondents (10.8%), and accommodation and food services with 372 respondents (8.36%). The top 4 categories represent 52% of the total employment in Portland. The remaining 16 employment categories by level of employment are: construction; education and training; transport and warehousing; agriculture forestry and fishing; wholesale trade; public administration and safety; professional, scientific and technical services; administrative and support services; financial and insurance services; rental, hiring and real estate services; arts and recreational services; electricity, gas, water and waste services; information media and telecommunications and mining.

Scenarios for Modelling

The population and housing scenarios are shown in Table 2. The scenarios were

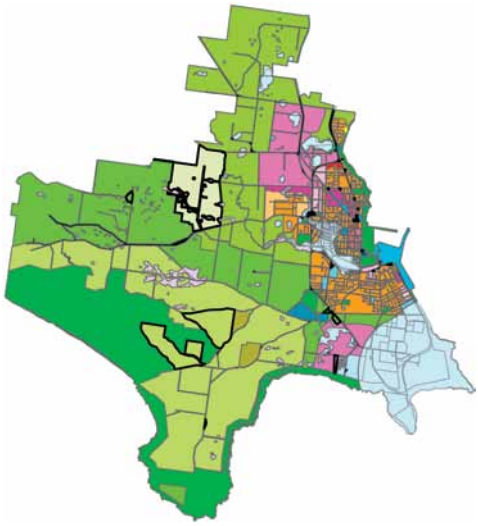


Fig. 9. Portland Development in 2016.
Source: [Herron, 2015].

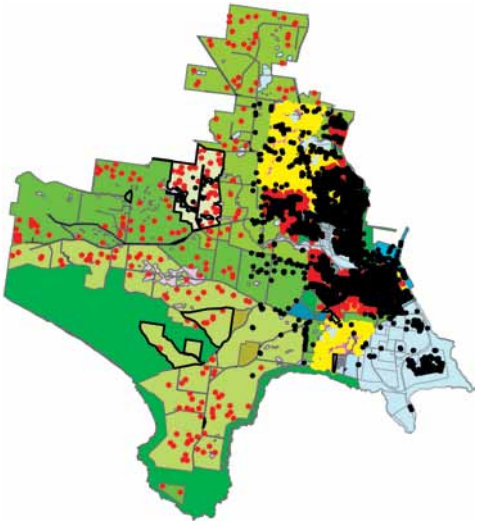


Fig. 10. Portland Residential, Commercial and Industrial Development in 2050
Source: [Herron, 2015].

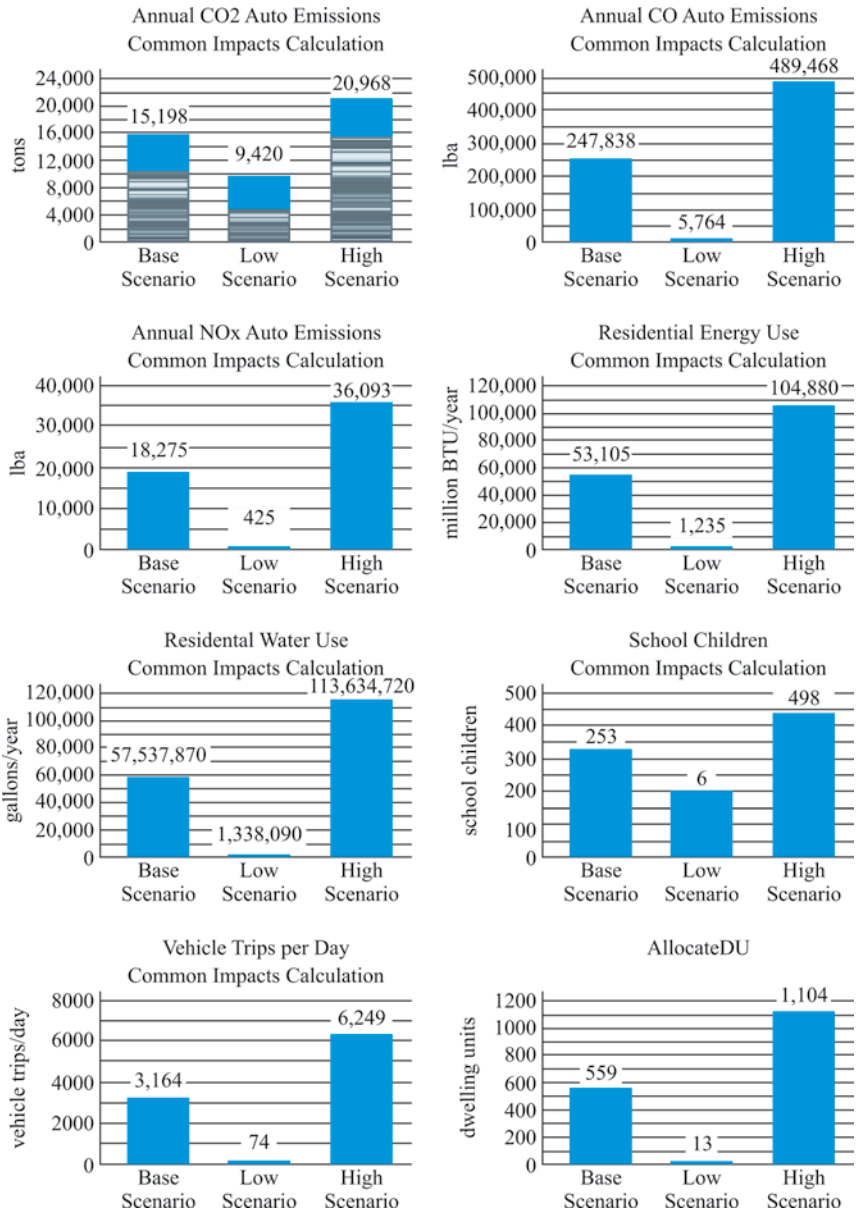


Fig. 11. Portland indicators for 2016

input to Community Viz software where the software performed three analyses namely:

- A **Build-Out analysis** that showed the residential, commercial and industrial potential for Portland from 2016 through 2050;

- A **Suitability Analysis** was done on the build out results. The suitability analysis used 8 criteria:

CBD proximity	Heritage locations
Sewer access	Proximity to Zone 2 industrial areas
Proximity to the smelter	Projected coastal movement from 2016 through to 2050
Shoreline access	Fertilizer plant

- **An Allocate analysis**. The allocate function takes the results from the build out and sustainable analysis and allocates the demand for buildings across the available supply of potential building locations

The result was a build out of potential residential locations up to the 2050. These locations were constrained by the eight suitability factors (CBD proximity, sewer access, proximity to the Smelter, shoreline access, fertilizer plant, heritage locations, proximity to Zone 2 and projected coastal movement from 2016 and 2050). The 4833 proposed dwellings were overlaid on the 3D model of Portland that showed all existing buildings and dwellings which highlighted the current and future growth corridors. The yellow dots top right corner of Portland in Fig. 9 represent residential dwellings and red dot s commercial/industrial developments for 2015.

Fig. 10 represents the combined development in Portland in 2050. Residential development is again represented by yellow dots while commercial/industrial development is represented by red dots. The pattern of residential development is similar with residential development located in north and south Portland.

With the proposed development a series indicators were developed including:

Residential Water Use	Annual CO Auto Emissions
Annual CO_2 Auto Emissions	Annual NOx Auto Emissions
Residential Energy Use	Vehicle Trips Per Day
Dwellings	School children

The 2016 results are shown in Fig. 11.

CASE CITIES: APOLLO BAY

Apollo Bay, situated on the Victorian coastline 187 km south of Melbourne. Apollo Bay is a small settlement with a population of 2,500. The major commercial activity is tourism. Fig. 12 depicts Apollo Bay's location, and Fig. 13 provides a demographic overview of Apollo Bay.

Apollo Bay's current issues include: increasing population, residential density issues, public transport issues, water quality concern, and a shifting economic climate. These issues led to Graymore [2008] posing the question of how useful current tools are for sustainability assessment at the regional scale. Additionally Apollo Bay is physically constrained in its growth by reserved forestry and conservation lands, and the steep to heavy undulating topography that envelopes its surrounds. Its growth can therefore only build upon and within the existing subdivided land in the town.

Methodology

The simulation exercise entailed the development of three scenarios (Low, Average and High) for the period of 2016 through 2050 (Table 3).

In addition to the projected population and dwelling numbers, physical and infrastructure constraints (i.e. water and sewer networks; electrical networks; transport networks flooding patterns; storm surge sea level rise and acid sulphate soils) were developed to further restrict and control the development.

The analysis took into consideration the physical and natural impediments and two other criteria:

- Areas which had shoreline access and
- Areas which had a close proximity to the central business district of Apollo Bay

The four combined criteria were used to rank areas in order of preference for new development areas shown in Figs 14 and 15.

Figure 14 and 15 shows where development will occur in 2016 and 2050. The light blue (sea level rise) and dark blue (storm surge) outlines on the Apollo Bay coastline shows the impact that the two factors will have on the Apollo Bay landscape. Development along the coastline is restricted over the time period because of the encroaching sea level rise with future development as indicated by Fig. 14 being focused or driven inland. Fig. 15 highlights the increased density pattern of future development. The modelling done for this research kept the same density parameters i.e. (dwellings per ha; minimum separation distance between buildings; layout pattern and setback distances).

Table 3. Growth Scenarios for Apollo Bay 2016 to 2050
Low/Base/High Scenarios

Scenario 1	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
Low Population	2577	2602	2784	2939	3082	3113	3145	3176	3208
Houses	3064	3092	3285	3440	3554	3589	3678	3790	3903
difference		28	221	376	490	525	614	726	839
Scenario 2	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
Medium Population	2577	2739	2931	3094	3245	3277	3310	3343	3377
Houses	3064	3255	3458	3621	3741	3778	3872	3989	4108
difference		191	394	557	677	714	808	925	1044
Scenario 3	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
High Population	2577	2766	2960	3125	3277	3310	3343	3376	3411
Houses	3064	3271	3475	3639	3760	3797	3891	4009	4129
difference		207	411	575	696	733	827	945	1065

Source: [Herron, 2012].

Results

Several indicators (Annual CO_2 Auto Emissions, Annual CO Auto Emissions; Annual NOx Auto Emissions; residential water and energy use, etc.) were generated to demonstrate the effect an increase in the population will have on the environment and landscape. Each indicator showed substantial increases the result of increased population or development pressures as shown by Fig. 16.

Fig. 12. Aerial Photo of Apollo Bay, Victoria.
Source: [Google Earth, 2014].

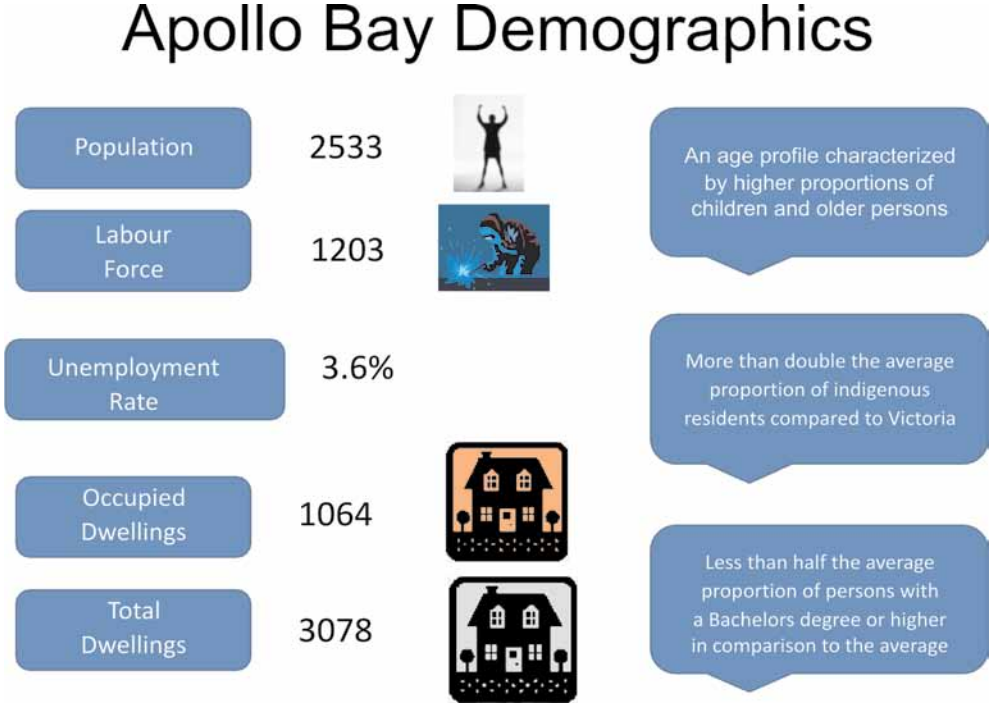


Fig. 13. Apollo Bay Demography.
Source: [iD Consulting, 2014].

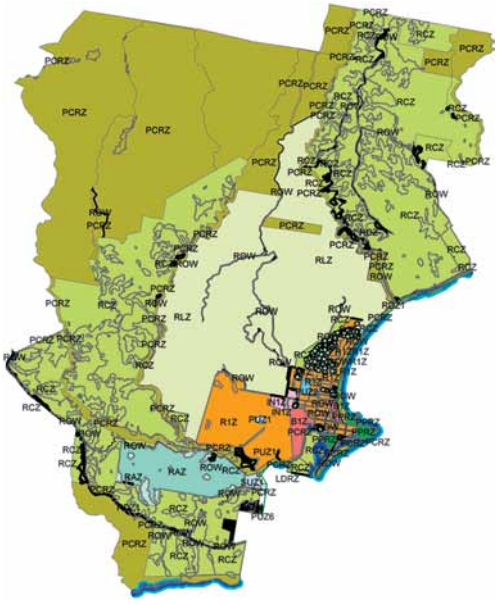


Fig. 14. Apollo Bay Development 2016.
Source: [Herron, 2015].

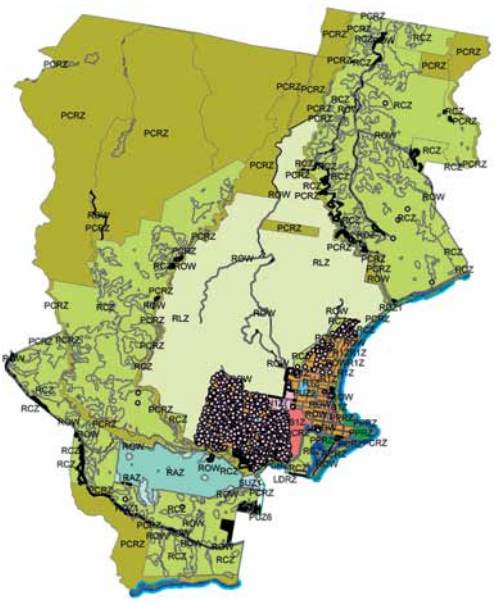


Fig. 15. Apollo Bay Development 2050.
Source: [Herron, 2015].

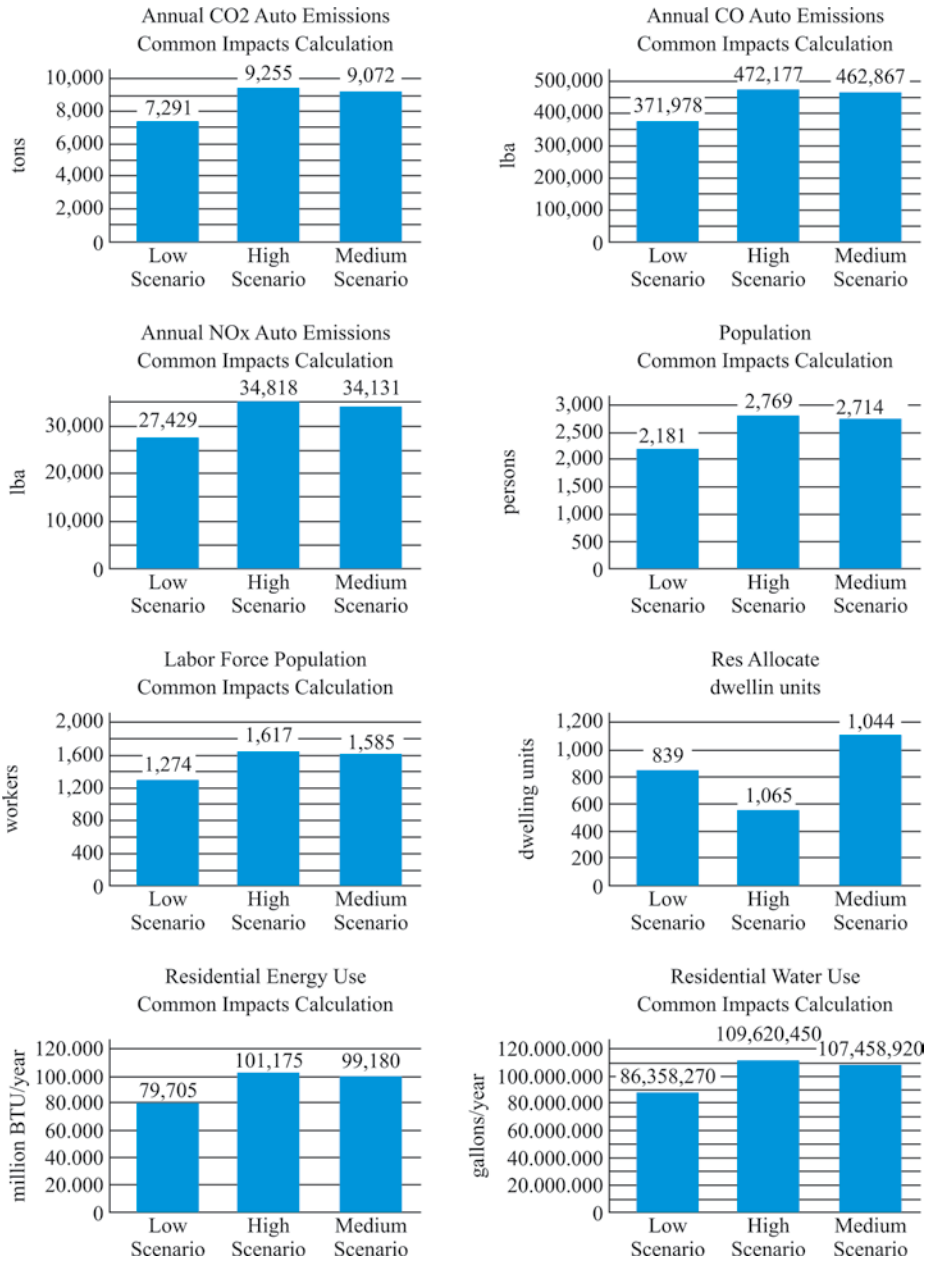


Fig. 16. Apollo Bay Indicators

CASE CITIES: ANGLESEA

The town of Anglesea (Fig. 17) is within the Surf Coast Shire, which is located in Victoria to the south of Melbourne and Geelong. Early development in the Shire dates from the 1850s due to its beaches and holiday lifestyle. Access to communities such as Anglesea was difficult until the opening of the Great Ocean Road in the 1920s. The Great Ocean Road enabled towns such as Anglesea to become tourist centres particularly with the advent of private vehicle transport. The Surf Coast Shire, experienced significant growth from the 1980s onward with key environmental and sustainability issues relating to this growth, specifically urban sprawl and increased degradation of the

Fig. 17. Aerial Image of Anglesea Victoria.

Source: Google Earth, 2014.

Table 4. Three Growth Scenarios for Anglesea 2016–2050
Low/Base/High Scenarios

Scenario 1	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
Low Population	2538	2543.3	2565	2571	2623	2808	2996	3196	3365
Houses	2887	2967	3048	3088	3127	3349	3573	3812	4013
difference		28	161	201	240	462	686	925	1126
Scenario 2	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
Medium Population	2538	2569	2591	2597	2649	2836	3026	3228	3399
Houses	2887	2997	3079	3119	3159	3383	3609	3850	4054
difference		110	192	232	272	496	722	963	1167
Scenario 3	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
High Population	2538	2826	2850	2857	2913	3120	3328	3550	3438
Houses	2887	3297	3431	3475	3721	3970	4234	4459	
difference		410	500	544	588	834	1083	1347	1572

Source: [Victoria, Department of Planning and Community Development, 2014].

environment. Additionally Anglesea is physically constrained in its growth by reserved conservation lands, a brown coal mining tenement, and the steep to heavy undulating topography that envelopes its surrounds. Its growth can therefore only build upon and within the existing subdivided land in the town.

The Anglesea population and housing are shown in Table 4.

Scenario Modelling Results and Discussion

Fig. 18 shows the following information on new development (i.e. new houses) in 2016.

Yellow dots represent residential dwellings and the red dots represent commercial/ industrial buildings. Fig. 19 shows residential development in 2050. The development is centred in the north and western portion of Anglesea.

Fig. 18. Anglesea in 2016.
Source: [Herron, 2015].

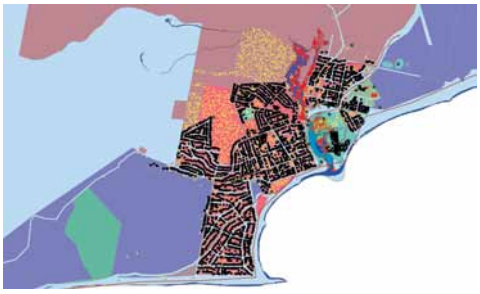
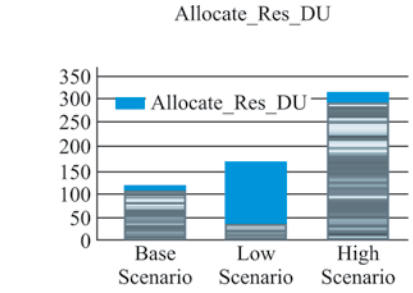
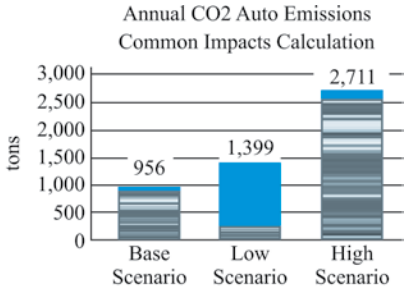
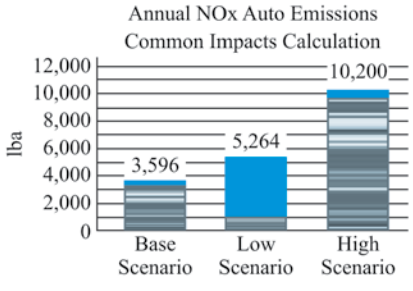
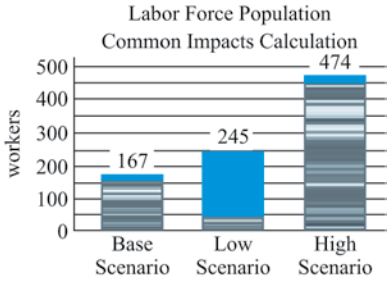


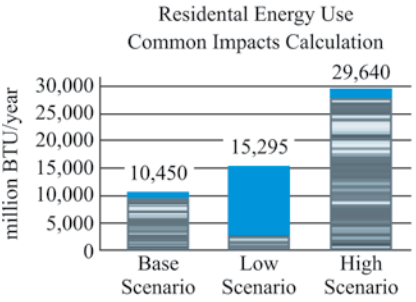
Fig. 19. Residential Development in Anglesea 2050.
Source: [Herron, 2015].

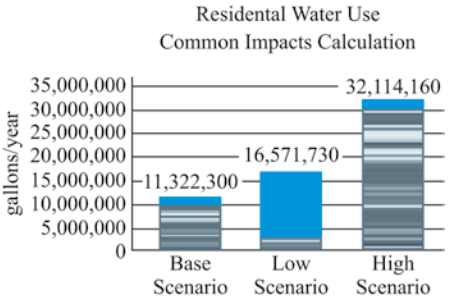












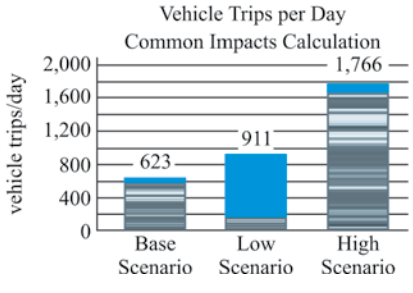


Fig. 20. Anglesea indicators for 2016

The growth in population and development to 2050 has the following impacts on the landscape of Anglesea. Fig. 20 shows the results of 2016 simulation and is indicative of the impacts, which will occur in Anglesea.

CASE CITIES: HOBSONS BAY

Hobsons Bay was created on 22nd June 1994 following the amalgamation of the former cities of Williamstown and Altona and includes parts of the suburbs of Laverton and South Kingsville. Hobsons Bay is situated on the north-western flank of Port Phillip Bay around 10 km west of central Melbourne. The City covers an area of approximately 66 km^2 (Fig. 21).

Hobsons Bay has over 20 km of bay frontage, quality residential areas, and a huge expanse of environmentally significant open space, and a range of major industrial complexes, that contribute significantly to the economy of Victoria. Hobsons Bay needs to address both current and projected issues of increased population growth; open space requirements; coastal flooding and storm surges; residential density issues; and, industrial land use issues.

Demography

The demography for Hobsons Bay is shown in Fig. 22.

With a population of 89,111 people, Hobsons Bay has a current population density of 1388.22 km^2. The City has an area of 64 km^2 in size comprising 41,686 parcels or lots of which 35,386 are occupied by private dwellings. Hobsons Bay has 10 dedicated parks and a 23 km of coast. It has a transportation system that includes a local and interstate bus network, and a metropolitan and regional train service. Hobsons Bay has recently completed an Urban Design Frameworks study for all the major settlement areas with the City. The dominant employment sectors are manufacturing which represent 11.3% of the workforce, healthcare at 9.4% and retail which represents 9.1% of the workforce.

Scenarios for Modelling

The scenarios used in this research are based on an integrated model of: population land use, transportation, and environmental projections from the City of Hobsons Bay and the Victorian and Commonwealth levels of government. Three scenarios (Table 5) were developed from the Victorian population and housing forecast to 2050. A low scenario equating to 90% of the of the Victorian government predicted population and housing growth forecast to 2050, a base scenario which is the actual Victorian government forecast and a high scenario

Fig. 21. Aerial Image of Hobsons Bay.
Source: [Google Earth, 2014].

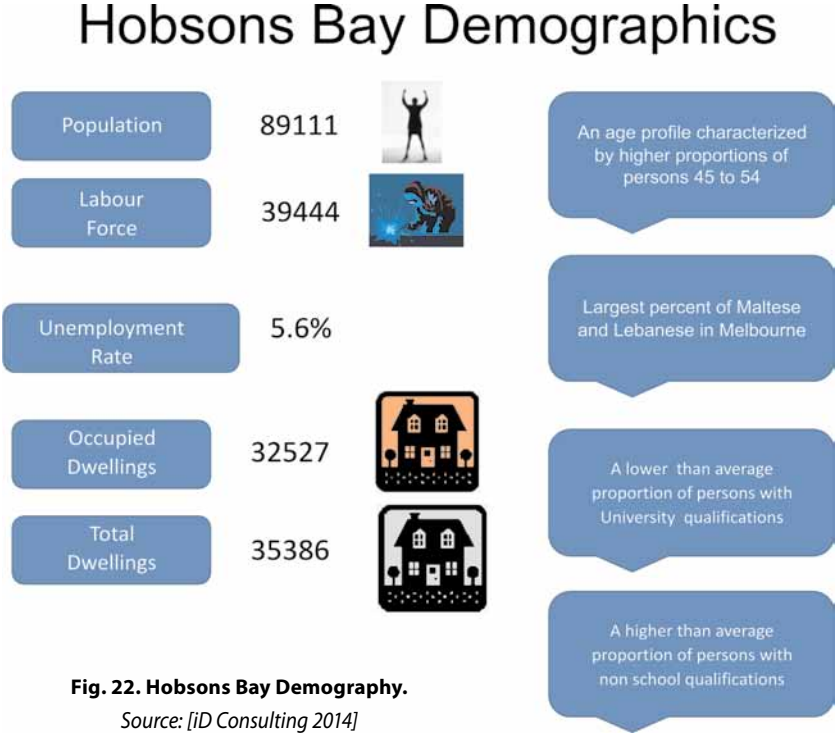


Fig. 22. Hobsons Bay Demography.
Source: [iD Consulting 2014]

which is 110% of the Victorian government forecast.

The Build-out, Suitability and Allocate analyses were performed on the Hobson Bay data. The suitability analysis performed on the Hobsons Bay build-out analysis result used 12 criteria including coast flooding projections from 2040 through 2100; proximity to oil refineries, chemical plants and oil tank farms; and trees and native vegetation.

Results

For the period 2016 through to 2050 the number of new dwellings constructed

Table 5. Three Growth Scenarios for Hobsons Bay 2016–2050
Low/Base/High Scenarios

	2016	2021	2026	2031	2036	2041	2046	2050
Scenario 1 Low Population	81996	84848	87602	90119	93,002	95,977	99,047	102,215
Total Dwelling	33370	34902	36359	37739	39,319	40,965	42,680	44,467
New Dwelling Units	1376	1432	1489	1549	1,611	1,675	1,742	1,812
Scenario 2 Average Population	91,107	94,275	97,336	100,132	103,335	106,641	110,052	113,572
Total Dwelling	37,078	38,780	40,399	41,932	43,688	45,517	47,422	49,408
New Dwelling Units	2111	2577	2224	2,342	2,184	2,419	2,407	2,528
Scenario 3 High Population	100,218	103,703	107,070	110,145	113,669	117,305	121,057	124,930
Total Dwelling	40,786	42,658	44,439	46,125	48,056	50,068	52,164	54,348
New Dwelling Units	2,753	2,974	3,211	3,468	3,746	4,046	4,369	4,179

Source: [Victoria, Department of Planning and Community Development, 2014]

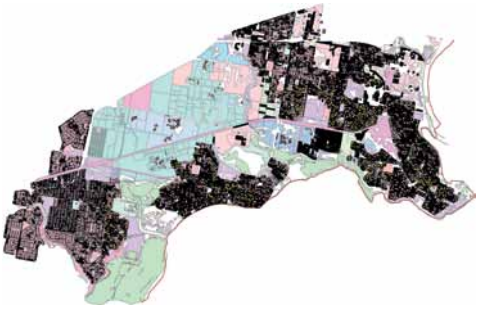


Fig. 23. Hobsons Bay Development 2016.

Source: [Herron, 2015].

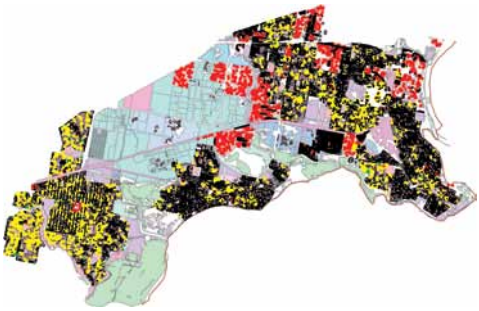


Fig. 24. Hobsons Bay Development 2050.

Source: [Herron, 2015].

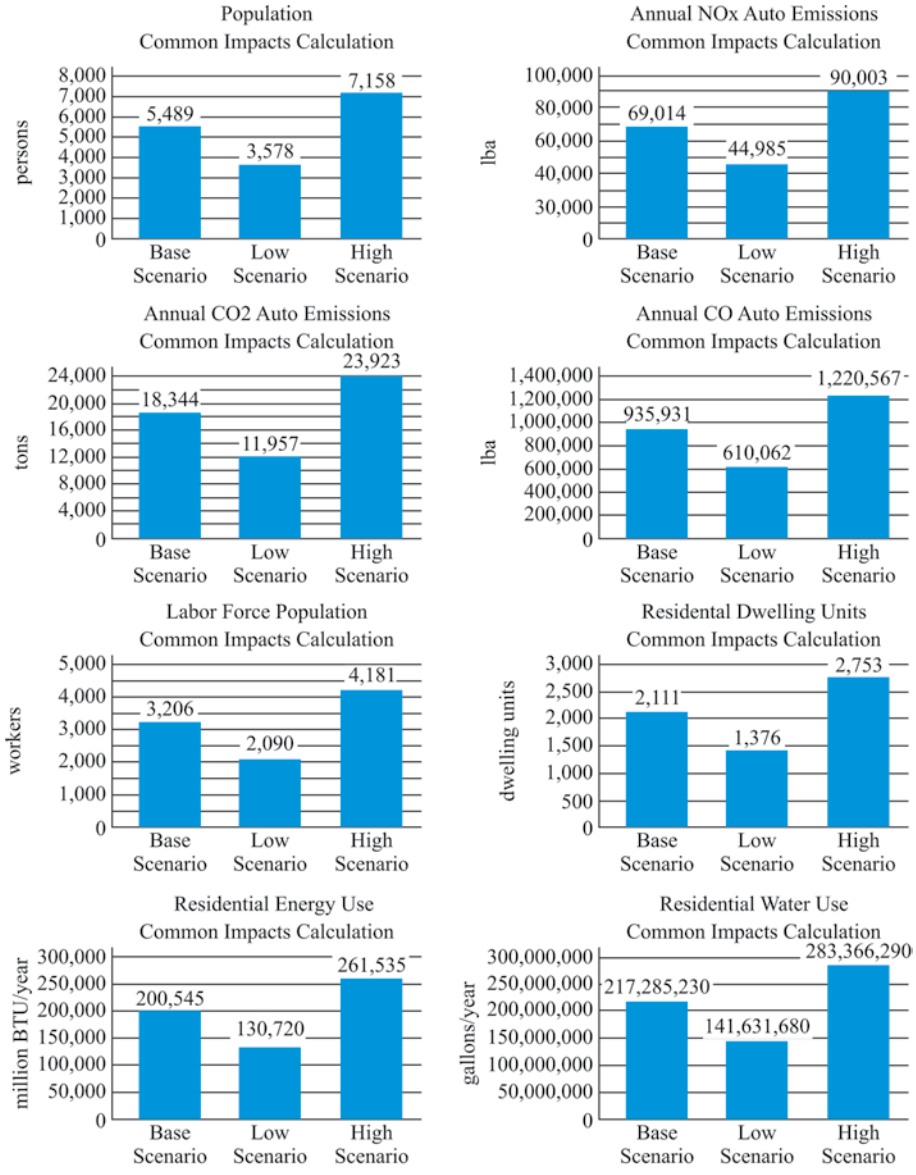


Fig. 25. Hobsons Bay indicators for 2016

could range from 12,686 to 28,746 dwelling units (Table 5). Fig. 23 shows residential development in 2016 and Fig. 24 shows development in 2050. Residential development is represented by yellow dots and commercial development by red dots.

Other issues that impact the future land use include: coastal inundation, increased temperatures, reduction in rainfall, sea level rise, soil degradation, long term employment outlook in the manufacturing sector. All of these factors impact the land use allocation and planning.

Every calculated indicator showed substantial increase being the result of increased population or development pressures as shown by Fig. 25.

DISCUSSION

The research undertaken for this paper relating to the four test sites has generated ten discussion points which are listed below

1. Population increases generating more emissions and greater impacts of climate change;

2. Increased consumption of energy and water resources;

3. Open space allowances decrease for new developments and General overall open space decreases per head of population;

4. Urban density increases;

5. For metropolitan areas (i.e. Hobsons Bay the scale of development) will increase;

6. For regional and rural locations (i.e. Portland, Apollo Bay and Anglesea) urban sprawl will increase as these locations have available land which will for new development;

7. New residential and or commercial development will add greater stress on existing physical and or natural infrastructure;

8. The exodus of more jobs (i.e. commercial and industrial jobs to peripheral areas and being replaced service industry jobs); and,

9. More mixed commercial/residential developments in the metropolitan and regional centres.

As indicated above, Portland, Apollo Bay, Anglesea and Hobsons Bay face the impacts of climate change and sea level rise, as well as various other impacts due to population growth and human activities. It is now accepted and reflected in various literature, as well as in government policies internationally, and in Australia that concern is warranted to address the potential impacts of climate change in regional coastal areas [Macintosh, 2012].

The results of the Community Viz simulation model as indicated in the various city sections, provided scenarios of future growth, issues relating to that growth and the corresponding risks. The decision making process regarding climate change is complex. The development of adoption processes to mitigate climate change by many governments involves using a risk management approach [AGO 2006].

To be able to deal with the many complex factors for adaptation, this paper proposes the use of an adaptation framework that includes the precautionary approach and the visualisation scenario modelling of Community Viz, considering a scenario-modelling framework.

Using the scenario-modelling process as above, the integration of Adaptation Planning will help Portland, Apollo Bay, Anglesea and Hobsons Bay respectively to plan for a possible sustainable future. However, this is a complex process and it is recommended to use the principles of the Design Based Adaptation Model (DBAM), adapted from Roös [2012] (Fig. 26) to suit the four community's growth scenario, as indicated in Tables 2 through to 5.

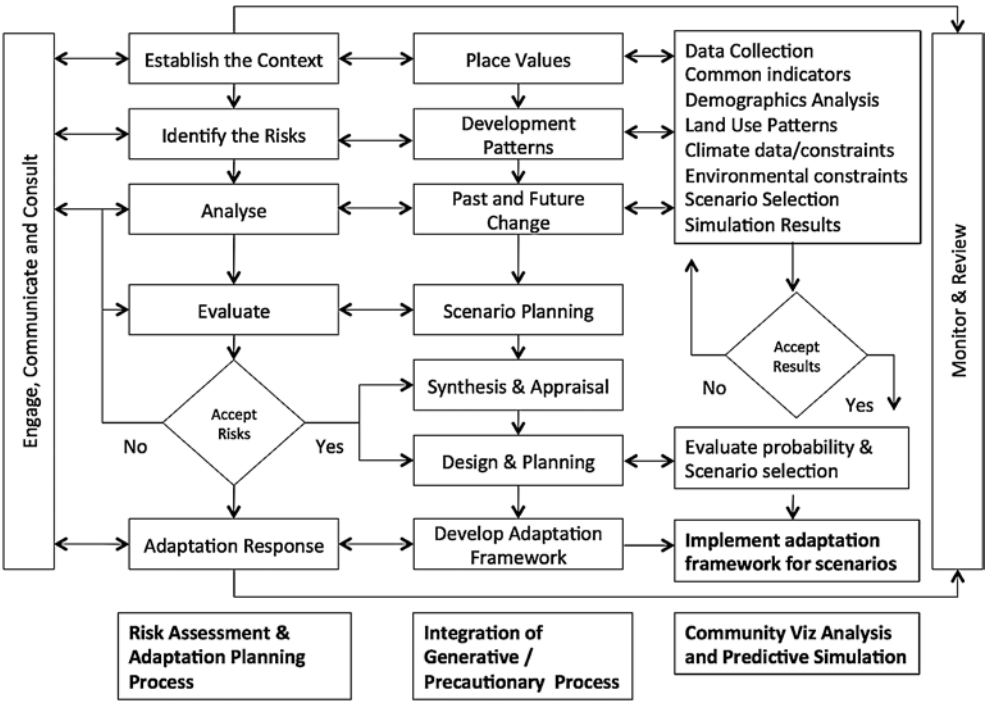


Fig. 26. Design Based Adaptation Model [Roös 2012]

The following 9 conclusions can be drawn:

Point 1 Population increases generating more emissions and greater Climate Change impacts. For each of the four research sites (Portland, Apollo Bay, Anglesea and Hobsons Bay) as the project population increases the environmental indicators used to highlight environmental degradation increased (i.e. CO, CO^2, Auto Emissions, residential water and energy consumption, etc.) The level of increase is predicated on the number of cars and individuals per household. The more individuals or cars per household the greater level of emission or consumption of water and energy per household. For the regional/rural sites (i.e. Apollo Bay, Anglesea and Portland) the opportunity of reducing the number of vehicles is remote as public transport has not developed into a reliable alternative to owning a motor vehicle. In the metropolitan areas (i.e. Hobson Bay) there is the possibility to reduce car numbers per household. This reduction is the results of mass public transport which is located in the metropolitan region.

Point 2 Increased consumption of energy and water resources as indicated by Figures 9–45 occurred for each of the study locations throughout the 40 year simulation period. Water and energy consumption will increase as the result of population growth. The level of increase can be reduced through water sensitive design and energy efficient equipment and appliances. The other point on increased energy consumption is the substitution of coal based generated electricity with electricity generated by renewable sources will reduce the impacts of climate change on the landscape.

Point 3 Open space ratio will decrease as a result new developments. The analysis show for communities that had prescribed city or township boundaries new development or increased development will reduce the

allotted opens space per head of population. For Hobsons Bay the advent of high rise developments has reduced and will further reduce the open space ratio for residents as well developments come on line. In the regional and rural study locations (i.e. Portland, Apollo Bay and Anglesea this was not a major issue as the reduction in open space was minimal).

Point 4 Urban density increases. The current population for Hobsons Bay is 90,000 with an urban density of 1,385 persons per ha by 2050 the population will be 125,000 with an estimated 1,922 per ha.

Point 5 For metropolitan areas (i.e. Hobsons Bay the scale of development will increase). Hobsons Bay has only a limited area to incorporate the additional 25,000 to 30,000 residents by 2050 density and the scale of development will need to expand. Hobsons Bay has just passed new building regulations and zoning regulations in 2014 that allow for the construction of taller residential buildings (i.e. up 30 storeys). Future regulations will increase the story limit to 50 stories.

Point 6 For regional and rural locations (i.e. Portland, Apollo Bay and Anglesea) urban sprawl will increase as these locations have available land which will be available for new development? Regional and rural communities in Victoria have not had their building regulations altered to allow for higher storied residential buildings in 2015. The 2015 height level is four stories. The three regional/rural study sites have a limited supply of residential land suitable for development. This shortage will become an issue before 2050 requiring additional new residential land to be made available for development purposes. The new residential land will add to the urban sprawl characteristics of the landscape.

Point 7 New residential and/or commercial development will add greater stress on existing physical and or natural infrastructure. Each of the four research sites will experience growth. The residential growth levels for the period 2016 through 2050 range from 35 to 50%. This growth will put stress on the natural infrastructure such as beaches, marshes and coast lines all of which are contained in the four study sites. The future residential development will require additional reticulated water and sewer systems. In the regional and rural study sites are serviced by a combination of septic sewer systems and reticulated

Point 8 The exodus of commercial and industrial jobs to peripheral greenfield sites away from the city centre. In Hobsons Bay and Portland industrial jobs are now being located in peripheral areas surrounding the respective locations as industrial land which is close to the city centres is being rezoned for residential purposes. The demand for residential land is such that current land uses are transformed into current and future residential areas.

Point 9 More mixed commercial/residential developments in the metropolitan and regional centers. The addition of the mixed use zone into the Victorian planning system allows for greater flexibility for mixed developments that contain both residential and commercial components. The four research locations each have had their planning legislation augmented to incorporate the new planning zone. Developers can obtain greater return through the use of mixed residential and commercial development.

CONCLUSION

The topic of land use planning is both complex and multifaceted. It is comprised of significant numbers of data sets, interdependencies, analyses, scenarios and outcomes. The research question specifically asked could visualization techniques portray the information so that it is easily understood and thus more likely to be used. Over 150 datasets, 100 assumptions, 100 attributes and 100

indicators were used in the spatial analysis of the four research locations. Through the process of visualization we saw what type of development would occur, where it would occur, when it would occur and the impact that development would have on the landscape and the environment.

The end product was a series of maps and charts that simply explained the proposed residential and commercial development of Portland, Apollo Bay, Anglesea and Hobsons Bay and it associated impacts till 2050.

A clear conclusion evident, when you compare all 4 coastal cities is that the impact of climate change will largely be as a result of coast line change and erosion arising from storm surges and water level increases. Subtle and least recognized co-impacts will be increases in the water tables within the cities resulting in changes to bore water supplies, increased flooding and ponding, artificial constant flooding of creek exits, wetlands and estuaries as a result of increases of water tables and sea water levels, major erosion impacts upon coastal edge road and bridge infrastructure thereby impacting upon the security of transportation, and increase risk of bushfire hazard. Bushfire, water table, estuarine flooding, and transport infrastructure impacts (compounded more so because the cities are totally dependent upon 2 exit roads in a time of bushfire event) are more concentrated in Apollo Bay and Anglesea due to their "at the edge" locations, whereas low-lying flooding and transport infrastructure impacts (and to a much lesser extent bushfire) will be more prevalent in Portland and Hobsons Bay. Thus, in all four instances long-established transport infrastructure historically erected to enable access to the aesthetic attributes of the beach and coast is at a corresponding risk to the coastal edge itself that has been the subject to the majority of climate change investigations, and the full-consequence of increase bushfire risk in Apollo Bay and Anglesea continue to be little comprehended and planned for. The research, while accordingly with conventional conclusions about prospective changes to the coastal edge as a consequence of climate change, has identified additional variables that are being little comprehended and incorporated in strategic planning; such variables may in fact have greater consequences upon human life and safety than previously understood. Thus research in need to be understand the complexity of climate change upon these cities and not be blinkered by the excessive literature rhetoric about coastal edge change but approach the topic holistically using a greater raft of technologies, scenario-making and perspectives. ■

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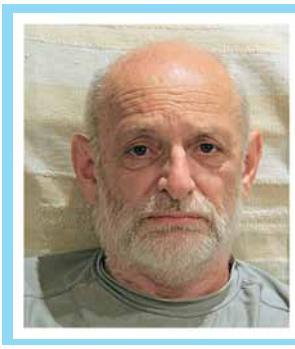

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DESIGNING ROADS IN GREENLAND USING GIS TECHNOLOGY

ABSTRACT. Designing a road in the Arctic (Greenland) which stretches 157 km between the towns of Sisimiut and Kangerlussuaq was very challenging. Difficult climatic and geotechnical conditions and presence of permafrost required some in-depth analysis and research. Geotechnical investigations were conducted along the entire route. The investigations included field geological and geophysical studies and survey using aerial photography. Based on the investigations a digital model of the area 2 km × 170 km was prepared. Using a Novapoint software a detailed geometric model was created which allowed for calculations of the volume of earthworks and creation of transverse and longitudinal sections of the road. A virtual model of the entire road and a movie were made based on the results of all investigations.

KEY WORDS: Greenland, geographic information system, digital 3D models, planned road, orthophoto, virtual map

INTRODUCTION

Greenland is the largest island on the planet, part of the Danish Kingdom. The total area of Greenland is approximately 2,4 million km^2, but only 384 850 km^2 are ice-free. The climate in Greenland is Arctic and even average summer temperatures do not exceed 10 °C. The population of Greenland is about 60 000 people and the main language is Greenlandic. Currently fishing and hunting still play a major role in the economy. The development of new oil fields and the development of the mining industry will require significant capital investment and will take many years.

One of the main obstacles to the development of Greenland is the lack of a well-developed transport network. There are no roads between cities and villages, no railways and inland waterways. Air transport is the easiest, fastest and affordable, but depends strongly on the weather conditions which are often adverse and unpredictable. Thus, the creation of a reliable network of roads that can be used in all weather conditions is a major need for the development of Greenland.

Sisimiut, the second largest town in Greenland, is at a distance of 150–170 km from Kangerlussuaq International Airport and intends to build a new road to the airport. The construction of such a road faces a number of technical problems that can be solved only with the use of state-of-the-art technology and construction methods. For instance, to select the optimal road layout requires extensive fieldwork, including geological, geodetic and geophysical surveys, determining the properties of the soils, and more. On the basis of these studies an aerial surveys along the full length of the planned road layout was carried out, and a detailed single orthophoto, measuring 2 km by170 km was created (Fig. 1). The results of all of these studies are summarized in a geographic information system.

METHODS AND DATA

The road is planned as a two way road, with a maximum axis pressure exceeding 15 tons. Maximum speed is planned to be 60 km per hour, road layout should avoid turning radii less than 30 m, and maximum slopes exceeding 12%.

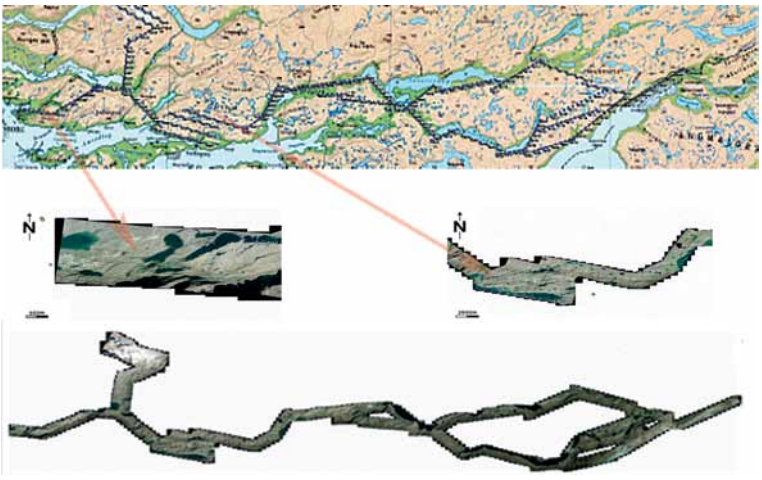

Fig. 1. Map showing the area and the orthophoto.

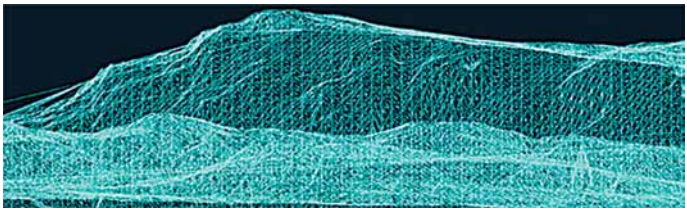

Fig. 2. Example of the constructed digital terrain model.

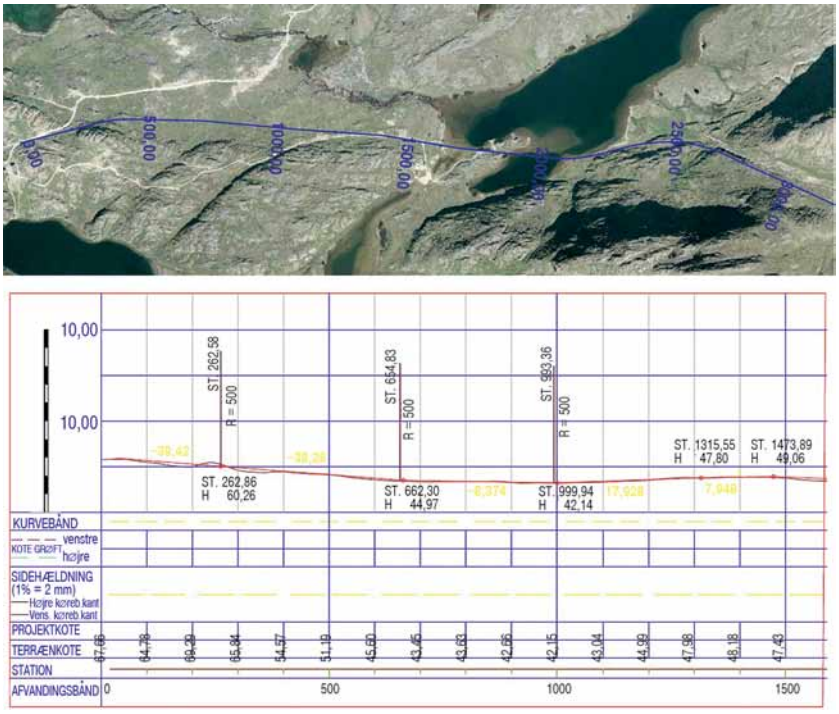

Fig. 3. Visualization of the planned road layout showing longitudinal and transverse profiles.

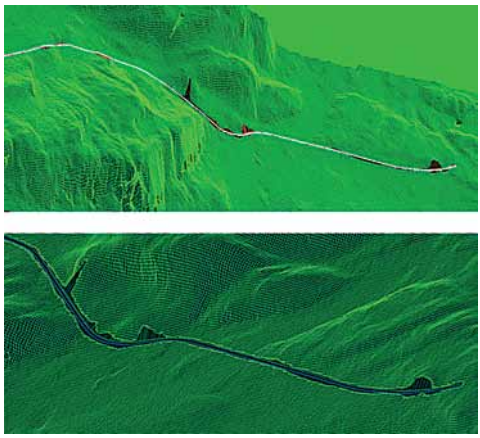

Fig. 4. Terrain and road model.

Fig. 5. Virtual map with the projected road layout.

Fig. 6. Image from the virtual trip by car.

A digital elevation model of 20 m resolution has been created on the basis of the constructed triangulation mesh (see Fig. 2).

Based on the data previously described the planned road layout is visualized in a longitudinal profile and characteristics for every 20 m (see Fig. 3).

The volume of material that needs to be moved to construct embankments or due to excavations was calculated. Together with spatial information these data were also included into the GIS system.

Fig. 7. Photos taken during the virtual overflight at 700 m above the ground.

The software Novapoint was used to create digital models of the terrain and of the planned road. Subsequently the two data sets were combined as shown in Fig. 4.

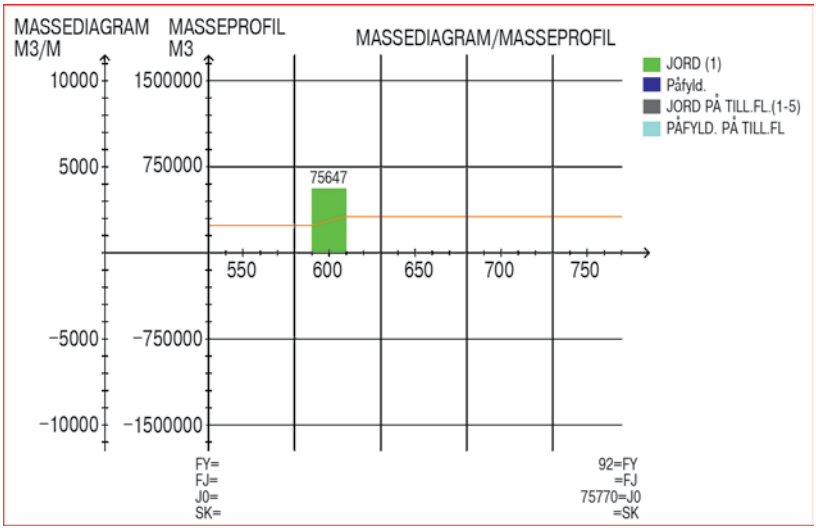

Fig. 8. Volume of road embankments and excavations along the planned road layout.

On the virtual map the orthophoto is used to visualize the projected road layout on the real terrain (see Fig. 5).

The combination of the orthophoto, the terrain model and the detailed road layout in the virtual map lets the user to move freely along the projected road. This visualization is very helpful in discussing and promoting the road project, as well as to monitor the impact of the planned layout. The images below are screenshots from a virtual trip along the planned road (see Fig. 6) and a virtual overflight at about 700 meters above ground (see Fig. 7).

Road embankments and excavations were calculated with the aid of the software Novapoint in the framework of Microsoft Excel. The calculations are shown in Fig. 8.

CONCLUSION

In the framework of this project, the focus was on the horizontal axis of the road relative to the terrain and on the geological conditions along the planned layout. The complete planned road layout (170 km) was finally divided into 6 individual sections, and the project has now moved into the implementation phase. The construction of a first section of the road, situated within the city of Sisimiut, has recently been started. The construction and maintenance of roads under arctic conditions needs to be done with special focus on the harsh climatic conditions. By creating an interactive virtual map of the Sisimiut – Kangerlussuaq road, an important part of the design and the implementation of the road layout was done. ■

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INSTRUCTIONS FOR AUTHORS CONTRIBUTING TO "GEOGRAPHY, ENVIRONMENT, SUSTAINABILITY"

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