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Interactive Comment

Interactive comment on "Comment on: "Recent revisions of phosphate rock reserves and resources: a critique" by Edixhoven et al. (2014) – Phosphate reserves and resources: what conceptions and data do stakeholders need for sustainable action?" *by* R. W. Scholz and F.-W. Wellmer

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Introduction

This review has been written in double-authorship by Bernhard Geissler (bernhard.geissler@donau-uni.ac.at) and Gerald Steiner (gsteiner@wcfia.harvard.edu).[1] During our own research we found that a lot of wrong or miss-interpreted information has been published over the last years regarding phosphorus, scarcity and the consequences for global food security. In this comment we want to take the opportunity to contribute to an ongoing fruitful discussion towards sustainable phosphorus reserves management on a global scale, from a systemic perspective.

The following comment addresses especially the discussion paper by Scholz and Wellmer (2015), which focuses on phosphate reserves and resources, as a comment on 'Recent revisions of phosphate rock reserves and resources: a critique' by Edixhoven, Gupta, and Savenije (2014). Additionally, the ongoing discussions and contributions by experts within the field like Cook (2014), Hilton (2013), Mew (2015) and, certainly, the origin of the discussion by Edixhoven, Gupta, and Savenije (2013) and the corresponding comments from Scholz and Wellmer (2013).

Generally speaking, the authors agree with the arguments pointed out by Scholz and Wellmer (2015) towards most shortcomings of Edixhoven et al. (2013, 2014). Although we are aware that the dynamics of reserves and resources were not the central issue of Edixhoven et al. (2013, 2014), we feel that this central concept should have gotten some more attention but not necessarily in the depth claimed by Scholz and Wellmer (2015) since this would have changed the overall focus of the paper itself.

[1] Both authors are members of the Global TraPs project, which was already part of the previous discussion. Gerald Steiner is the corresponding co-author of chapter 7 "Trade and finance as a cross-cutting node" in Scholz, Roy, Ulrich, & Hellums (2014) as well as the supervisor of Bernhard Geissler's master thesis "Sustainable Phosphorus Mining". Additionally, both authors are part of an international research group on efficiency within phosphorus mining, with Gerald Steiner also being core member of the 2012 phosphorus workshop in *Morocco* and the 2013 GPNP and Global TraPs World Conference in Beijing. Most recently, Geissler and Steiner are part of a team of authors involved in a Special Issue of "Resources, Conservation, and Recycling" on "Losses and Efficiencies in Phosphorus Management" (which included an author workshop organized by Fraunhofer IGB and University of Zurich).

Nevertheless, we see the comment by Scholz and Wellmer (2015) as very valuable and necessary additional information on Edixhoven et al. (2013, 2014) since it will help to prevent potential misconceptions. Our thoughts on the ongoing scarcity discussion should guide the dialogue into the direction of global phosphate distribution and management.

The comment is divided into three main sections, the issue of scarcity and criticality of reserves, a discussion on reserve and resource estimations, and finally, the concept of dynamic interactions between resources, reserves, and geopotential.

Scarcity and Criticality within the near-, mid-, and long-term Future

The latest report (2015) of the United States Geological Survey (USGS) states reserves of 67.0 Gt phosphate rock (PR) for the year 2014 (Jasinski, 2015) where *Morocco*[2] accounts for 75% of the global reserves. It is stated, and therefore the work of Edixhoven et al. (2013) has to be very much acknowledged, that this number includes marketable product (concentrate) as well as reserves in terms of ore and grade (explicitly mentioned in the 2014 commodities summary report for the first time). The calculation by Scholz and Wellmer (2015), with the adaption pointed out by Mew (2015), shows a required correction to 58.5 Gt marketable phosphate rock concentrate (PR-M), in the worst case (i.e. every country besides *US*, *Australia* and *Morocco* reported ore instead of concentrate); this would increase *Morocco's* reserves to 86%.

Scholz and Wellmer (2015) acknowledged the vast difference between sedimentary and igneous ore grades and used an average ore grade of 20%. On this basis, we performed the same calculation for the main igneous ore countries *Brazil*, *Russia*, and South Africa with average ore grades of 11.1%, 10.1% and 7% separately (based on country data provided by CRU for 2013) We find a necessary reduction of 0.8 Gt PR-M

[2] including the disputed territory of Western Sahara (in the following only referred to as *Morocco*)

which results in total world reserves of 57.7 Gt PR-M for the worst case (in terms of reported amounts of ore respectively concentrate).

Based on the actual figures (Jasinski, 2015) the authors are in-line with the forgone comments (Hilton, 2013; Mew, 2015; Scholz & Wellmer, 2013, 2015) that the world will not be running out of phosphate rock any time soon. From our point of view the interest in phosphate rock shall rather be focused on:

i) Global geopolitical strategies to minimize the short-term supply risk and avoid a state of critical urgency (i.e. criticality)

ii) Accessibility and management strategies on a global level for the mid- and long term in order to avoid economical and physical scarcity

The geographic distribution of reserves is mostly not in balance with most countries' production volumes (illustrated by Table 1). Therefore, based on country specific settings like present resources, current infrastructure, geopolitical stability, tax and royalty settings or environmental regulations, various possible solutions and strategies should be considered in order to reach the global goals pointed out above.

To substantiate our statements we want to discuss exemplarily the cases of *Syria* and *Brazil* at this point. *Syria* holds 1.8 Gt of phosphate rock classified as reserves (although not stated if marketable PR-M or phosphate rock ore [PR-Ore]), in terms of global reserves the country ranks in fourth position. The current production volume of 500.000 tons PR-M plays a diminishing role on the global market and in the short-term any kind of investment in order to raise the volume seems very much unlikely. The unpredictable political situation and recent events like the Arab Spring or the actual civil war between government and armed anti-government groups may have contaminated *Syria* in the long-term for foreign investments. *Brazil* on the other hand ranked fifth in terms of global production volume in 2013 with only 270 million tons PR-M (classified reserves) left, which could even be reduced to 65 million in case PR-Ore was reported (the potential vast reduction is due to the igneous nature of phosphate ores in *Brazil*). What we conclude from these cases is that for *Syria* on the one hand although being a country considerable rich in reserves, we most likely will not see any major expansion of production volumes due to geopolitical risks. On the other hand *Brazil* is ranked fifth in terms of production but faces the challenge to either explore new reserve depots or to rely on a price increase (or radical technical improvement) which turns economically unfeasible resources into feasible reserves. *Brazil* was chosen in order to present an example of countries with relatively high production volumes compared to the classified reserves, *Syria* exemplarily represents countries rich in reserves with limited chances of becoming a major supplier in the near- or mid-term future.

By taking a look at the national R/C ratios (Reserves/ Consumption [i.e., production])[3], we find the following figures for the five countries with the highest reserves and/or the ones with the highest production, according to the most actual USGS mineral commodity summary (Jasinski, 2015). We are fully in line with the argument by Scholz and Wellmer (2015) that R/C ratio developments over time shall only be considered as an early warning indicator. Still, we decided to take a closer look on the ratio not only on a global scale, but on a national level. The use of isolated country based R/C ratios may be questionable but in case of a carefully consideration within the country's political structure it might offers additional value since R/C ratios are rather simple to understand and communicate -especially to the public. The latter is certainly of interest in case of justifying publicly unpopular measures (e.g., exploratory drilling, capacity expansions) which might be necessary to avoid supply risks.

Table 1 represents a snapshot of the year 2013/14 containing production data (2013) and reserves (2014) on a country level, additionally to the USGS data the calculation of

[3]the ratio was already extensively debated in the ongoing discussion

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Scholz and Wellmer (2015) was used to illustrate what would happen to the countries' reserves in case PR-Ore was reported instead of PR-M. The decision to focus on the five countries with the highest production volumes as well as the ones with the highest reserves shall illustrate the massive differences in the R/C ratio between reserve rich and production intensive countries (e.g., *Morocco*), the ones which may be running out shortly[4] (e.g., *Brazil*) and those which may have to ramp up their production volume in terms of global supply security (e.g., *Australia*).

Table 1. Production volumes [Mt, share], reserves [Mt, share] & R/C ratios (*2013, ** reserves reported by USGS in terms of ore and grade for 2014, *** worst case scenario based on Scholz & Wellmer, 2015)

Country	Production*	Reserves**	Reserves***	R/C**	R/C***
Morocco	26.4 [11.73%]	50,000 [74.63%]	50,000 [86.7%]	1893.1	1893.1
China	108 [48%]	3,700 [5.52%]	1,609 [2.79%]	34.3	14.9
Algeria	1.5 [0.67%]	2,200 [3.28%]	957 [1.66%]	1466.7	638
Syria	0.5 [0.5%]	1,800 [2.69%]	783 [1.36%]	3600	1566
South Africa	2.3 [1.02%]	1,500 [2.24%]	227 [0.39%]	652.2	98.7
United States	31.2 [13.87%]	1,100 [1.64%]	1,100 [1.91%]	35.3	35.3
Russia	10 [4.44%]	1,300 [1.94%]	284 [0.49%]	130	28.5
Brazil	6 [2.68%]	270 [0.4%]	65 [0.11%]	45	10.8

Regarding the leading producing countries one can see that two out of three, namely *US* and *China* show an R/C** ratio of 35.3 respectively 34.3 (14.9*** in case PR-Ore was reported), which is extremely far behind to 1893.1 by *Morocco*. Although both countries (*US* and *China*) show similar R/C ratios of approximately 35, the conclusion of a similar situation would be fatally wrong. In the Western Phosphate Field (WPF) of the *US* many, especially underground mines, had to be closed due to rising min-

[4]in reference to the actual reserves, involving the simplified assumptions: constant prices, no radical technological change and no major exploration success of reserves

ESDD

6, C56–C68, 2015

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ing costs and low price competition from Florida and North Carolina (Jasinski, Lee, & Cuasey, 2004), which means, given the dynamics of reserves and resources, at higher market prices production in these areas can relatively easy be re-established. *China* on the other hand cannot fall back on once operated infrastructure (at least not in the same extent), hence necessary exploration activities are not comparable at all, especially in case of igneous ore exploration which tends to be more difficult due to the different geological characteristics. A further notable difference might be found in the divergent environmental regulations of both countries, which have to be taken into account during proceedings such as planning, exploration, excavation and primary beneficiation. In countries were the legislator equals the owner and operator of the mining and exploration sites competitive advantages in form of environmental regulations or trade (import and export) restrictions might arise.

While the calculations above are rather simple and straight forward, Cooper, Lombardi, Boardman, and Carliell-Marquet (2011) and especially Walan, Davidsson, Johansson, and Höök (2014) performed extensive simulations on the future supply distribution of phosphate rock which indicated major supply dependencies on single countries. In a scenario in which the global production is mainly dependent on one single country (e.g., *Morocco*), it is highly doubtful if this country might be able to raise the production capacities up to desired demand without compromising the long-term social and ecological surroundings of the mines and processing plants.

To summarize the attention should be shifted from the discussions of depletion to mid- and long term supply strategies. Additionally we should aim to reduce geopolitical risk, especially when we consider recent events like the Arab Spring.

Discussion on Reserve and Resource Estimations

In terms of the ongoing discussion on reported reserve estimation we do acknowledge the idea of a global actual inventory, but we are in line with Scholz and Wellmer (2015)

ESDD
6, C56–C68, 2015

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and Mew (2015) that companies do not want to spend money on these endeavors, since there is no direct influence on the business success within a realistic live-time period of an enterprise. Kreuzer and Etheridge (2010) took a closer look on success rates (probability of a project delivering a desired financial outcome) in mineral exploration: They distinguished brown- and greenfield operations, whereby brownfield involves exploration on mine sites or areas close to known depots. Greenfield specifies mainly unexplored territory although exploration for different commodities may have taken place. Given the status of a low price commodity (Scholz & Wellmer, 2015) greenfield operations without indications for phosphate rock (due to previous exploration for high value commodities such as diamonds or uranium) seem currently rather unlikely. The investigation of Kreuzer and Etheridge (2010) was based on mineral exploration in general (not solely phosphate rock related) and the published figures ranged between 1 in 24 for brownfield explorations and between 1 in 1,000 and 1 in 3,333 for greenfield explorations. Which means only 1 in 24 exploration targets (in their case a well-endowed gold district) becomes economically profitable. One possible way for improving the accuracy of the global inventory may become available through technological improvements in the field of geophysical methods as pointed out by Teixido (2012) and Asfahani, Aissa, and Al-Hent(2005).

In general, the difference between private and state-owned companies becomes evident. Where publicly quoted companies (e.g. *PotashCorp* or *Mosaic*) have to follow the interests of their shareholders, which usually seek profit maximization through dividends and rising stocks, state-owned private companies like *OCP* are supposed to act in the best interest of the national society. The latter have in principle a longer planning horizon and more incentives to be sustainable since the resources account for state assets.

Additionally we want to substantiate the argument on major mining companies moving into the phosphate business. According to data from Ernst & Young, provided by

Statista (2014b) in 2013, 18 global deals happened in the potash/phosphate commodity business segment with a total value of 6.0 billion US dollars (in comparison 12.0 billion within gold and 9.1 within the oil and gas segment), whereby the deals involving the Russian potash giant Uralkali accounted for approximately 5.5 billion (Statista, 2014a).

In order to condense the previous paragraphs; although we do support the call for a global inventory we do not think that the required long-term data will be provided by companies voluntarily due to factors like associated costs or strategically disadvantages.

Dynamic Interactions of Reserves, Resources, and Geopotential

Within the ongoing discussion a lot was already said on the dynamics of reserves and resources. While Edixhoven et al. (2014) only briefly indicated the dynamic boarders between reserves and resources, Scholz and Wellmer (2015) placed a huge emphasis on this issue. In summary they distinguish three different types namely, reserves, resources and geopotential. While *reserves* are known and can be processed at the current price *resources* are known up to a certain level but cannot be processed due to factors like low ore grades or aggravated mining conditions. The third group, *geopotential*, are the reserves and resources of the future (Scholz & Wellmer, 2015).

We do support the concept that technological developments in the future may provide further possibilities in terms of phosphate rock mining, particularly, as some of these technologies can only marginally be accessed today for various reasons (e.g., current prices do not justify the cost of additional [available] technology as pointed out by Scholz and Wellmer, 2015, in terms of the Western Phosphate Field). However, today unknown innovation-based disruptive changes in mining procedures can potentially lead to a much higher proportion of mined low-grade ores in the future.

ESDD
6, C56–C68, 2015

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In this years' commodity summary, Jasinski (2015) mentioned explicitly the possibility of offshore PR dredge mining in *New Zealand* and *Namibia* for the first time. A closer look into the latter project (i.e. Sandpiper) resulted in the information that the venture has been suspended for 18 months by the *Namibian* government in September 2013 for environmental concerns regarding the marine ecosystem and effects on the fishing industry. The government and especially the opposite party of seabed mining called for further studies on the effects of the technology (Benkenstein, 2014). Regardless of the outcome of this process, we do hope that further, hopefully less controversial, radical innovations emerge in order to secure a balanced long term supply (e.g., recycling of various waste streams and/or secondary mining of tailings).

Independent of the position one takes with respect to the preferability of fracking (brought up by Scholz and Wellmer, 2015) as an example to illustrate the meaning of a radical technological breakthrough), it is an interesting example for the extractive industry if it is considered from various perspectives: While the *economic* impact of such a technology may affect the overall price structure of a commodity (for this case, crude oil), the *ecological* consequences are not yet known to their fullest. In terms of *social* and *geopolitical* effects hydraulic fracking led to a reduced dependency of the *US* from the *Middle East* (decreased supply risk) with major implications on recent price developments.

To finally conclude our comment, we deem that the recently raised global attention on phosphors should be shifted toward long-term strategies. Indicators like country-based R/C ratio might be useful, but should only be considered carefully with respect to the national structures. A global inventory would be very valuable for the long-term reserve management. The implementation involving questions like 'Who?' and 'How?' seems to be an interesting issue and requires further thoughts. Although we think that a lot of potential is given for radical innovations the arising technologies have to be considered from more than just the economic perspective.

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6, C56–C68, 2015

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