

SUPPLEMENT TO FOURTH REVIEW

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| A | <p><i>"The detailed appraisal by Roland Scholz and Freidrich-Wilhelm Wellmer much more accords with my reading of the article rather than that of Reviewer #1. Accordingly, I have largely restricted my comments to those not already covered in the existing reviews."</i></p> | <p>We have discussed each of the comments of Scholz and Wellmer in our response to the second review and, more particularly, our detailed 23 page supplement which we posted on the ESD discussion forum on 23 December 2013. In our response to the second review, we noted that it did not discuss any of our research questions and only fractions of our research findings.</p> <p>The third reviewer noted that we addressed/considered/commented on the criticism in the second review. However, unlike the third reviewer, the fourth review, dated 5 March 2014, does not seem to have considered our responses. Likewise, the fourth review contains no discussion on our research questions and findings.</p> |
| B | <p><i>"We are indeed at risk "if society fails to take the appropriate steps to use this finite resource in a more diligent manner", although I would suggest substituting "efficient" for "diligent"."</i></p> | <p>We are in agreement with the recognition that "we" are at risk if society fails to take the appropriate steps. We agree with the suggestion to substitute efficient for diligent.</p> |
| C | <p><i>"Our increasing predilection worldwide for animal protein certainly has a major bearing on the issue and as consumers of meat we create the forces that drive 85% of the demand for phosphate fertilisers (Sutton et al (UNEP) 2013). But the question is how should society address this issue? What are the appropriate steps? Are we clear what the problem is that we are trying to solve? What for that matter is meant by society? The paradox of the current time is that ~1bn people suffer from hunger and chronic food insecurity, while approximately the same number, and growing, suffer from obesity and high risk of type 2 diabetes. Is it, as the authors conclude, to find out what "society" should do "once today's reserves and resources are depleted"; or is it that at least part of the answer lies in the here and now and concerns our eating habits."</i></p> | <p>As we made clear in the paper as well as in our response to the second review, our paper poses three research questions: (i) How does IFDC's simplified resource terminology compare to international resource classification and is it likely to yield data which are transparent, comparable, reliable and credible?; (ii) is the difference between ore and concentrate sufficiently noted in the literature?; and (iii) is the estimate of PR reserves in the IFDC report reliable. These questions are considered important by the first and third reviewers and a sufficient basis for publication. While the questions posed in the left hand column are important, they are beyond the scope of our paper.</p> <p>Other than the reviewer states, we did not conclude that issues of phosphate management can be resolved by finding out "what society should do 'once today's reserves and resources are depleted". This is clear from the quoted section in our paper which, in its entirety, reads as follows:</p> <p><i>"A truly independent and scientifically sound global inventory of PR deposits, as envisaged in the report, is yet to take place. Such review would also need to realistically assess those deposits which are not currently viewed as resources and which humanity will come to depend upon once today's reserves and resources are depleted."</i></p> |
| D | <p><i>"Surely the assumption that PR resources will inevitably be depleted is wrong; but I agree that if we do not change a variety of industrial and consumer behaviours the risk of depletion certainly goes up."</i></p> | <p>In our paper, we did not state or suggest that aggregate PR deposits will inevitably be depleted, to the effect that there will be no more resources or reserves available. Rather, our paper discusses that reserves and resources are dynamic and that reserves and resources as currently acknowledged will be replaced by new reserves and resources as resources are upgraded to reserves, occurrences are upgraded to discoveries and</p> |

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| | | <p>new discoveries are made. This is apparent from our paper and our response to the second review, where similar comments have been made.</p> <p>The second reviewer agrees that the risk of depletion goes up if society does not change a variety of industrial and consumer behavioural patterns.</p> |
| E | <p><i>"Some Causes of Uncertainty and Error in Reporting PR Resources and Reserves</i> <i>There are many factors influencing why it is so difficult to generate accurate and transparent data about global PR resources and reserves. These include:</i></p> <p><i>[numbers 1-13]"</i></p> | <p>The fourth reviewer raises 13 points why it would be difficult to generate reliable data on PR and, having discussed them, concludes that these factors will render it less and less likely that major PR producing countries and companies will disclose their hands in terms of the PR deposits they command. The underlying message of this part of the review, it seems, is that it would be not very worthwhile to devote efforts and resources in obtaining reliable data on PR reserves, resources and occurrences.</p> <p>In our response to the review, we already generally responded to these comments. Below, we will discuss each of these comments in more detail.</p> |
| E.1 | <p>Nr. 1. <i>"The very uneven distribution and varying genesis (sedimentary, igneous, etc) of PR worldwide"</i></p> | <p>We have described the uneven distribution and varying genesis of PR in our paper. We do not think this circumstance should prevent generating reliable information. As explained in our paper, if a deposit is insufficiently measured or if its economic viability cannot be assessed, it should be reported accordingly.</p> |
| E.2 | <p>Nr. 2. <i>"Reporting requirements such as JORC and National Instrument 43-101 (Canada) serve primarily to protect investor interest. The major mining and processing companies are notorious for understating reserves, while Juniors tend to over report, because they want to attract investors. UNFC may in part address such an asymmetry by making statements about resources and reserves, and about resource progression, easier to compare across classification and reporting systems. But there is no immediate prospect of either JORC or National Instrument 43-101 being replaced by UNFC. UNFC (2009) is itself relatively silent in its current form on sustainability issues, a matter now being addressed by UNECE EWGRC."</i></p> | <p>In our paper, we have discussed investor related JORC style codes and their rationale.</p> <p>The reviewer agrees that UNFC classification may be used to compare statements on reserves and resources among the various classifications. He also correctly states that there is no immediate prospect of investor codes being replaced by UNFC. However, the relevant issue is that statements of reserves, resources and other occurrences should be comparable so that they can be properly examined. The UNFC classification is an important tool for this, but can only be used if data are reported with sufficient detail and with sufficient consistency with UNFC to allow mapping with UNFC (UNFC, 2013).</p> <p>The reviewer argues that the major mining and processing companies are "notorious" for understating the reserves. However, he provides no source for this statement nor is the economic logic behind this apparent.</p> <p>The reviewer states that the UNFC is relatively silent on sustainability issues. However, it is clear from the previous as well as the current version of UNFC (UNFC, 2010 and 2013) that the classification is also designed to enable the establishment of comparable longer term inventories to establish a picture of the future supply base:</p> <p><i>"Establishing a complete picture of the current and future supply base of fossil energy and minerals is necessary for effective resource management. Accurate and consistent estimates of fossil energy and mineral reserves and resources, coherent with other scientific and social/ economic information, are the</i></p> |

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| | | <p><i>foundation for such assessments."</i></p> <p>And:</p> <p><i>"It [UNFC-2009] provides a single framework on which to build international energy and mineral studies, analyze government resource management policies, plan industrial processes and allocate capital efficiently"</i></p> <p>The preface of UNFC (2010) stresses the importance of sustainable management of mineral resources, albeit in the context of energy:</p> <p><i>"Sustainable energy development is dependent on careful management of the world's non-renewable energy resources, i.e. oil, natural gas, coal and uranium. UNFC-2009 has an important role to play in this process."</i></p> |
| E.3 | <p>Nr. 3. <i>"The shift in the balance of power, and of production, in the phosphate sector from developed to developing / emerging economies. For example, the United States now imports rock from Morocco to keep up with fertiliser production targets in significant measure because of resistance to PR mining in the US."</i></p> | <p>The reviewer does not explain why a shift in market control would keep countries or producers from "disclosing their hands" in terms of the PR resources they command or why this would impair the ability of generating reliable PR data in general. No reference is provided. We feel that this comment is beyond the scope of our research questions.</p> |
| E.4 | <p>Nr. 4. <i>"Many emerging/ developing economies depend heavily on their P resources for earning hard currency, for example Morocco, Jordan, Tunisia, each of which also relies on the PR mining and processing industry to be one of its principal pillars of GDP. These countries are under no equivalent pressure to public companies listed in Europe, North America or Australia to disclose what resources and reserves they command; and given current trends of acquisition by China and Russia mining companies reporting under JORC or National Instrument 43-101 are likely to represent an ever smaller proportion of the mining industry in general, and PR in particular. So resource data may be withheld for commercial and/or strategic reasons over which stock exchanges and UNFC have no control. (data on water resources is commonly withheld by governments for similar reasons). There is an obvious commercial risk to a highly traded product such</i></p> | <p>The reviewer points out that increasing the reported reserves may result in downward price corrections which could harm the fragile economies which depend on them. The reviewer does not provide a source for this statement.</p> <p>It does not seem evident to us that an increase of reported reserves or resources would result in lower prices. We note that four-fold increase of global reserves in the IFDC report in September 2010 and USGS' restatement of Moroccan and global reserves in early 2011 do not seem to have had a noticeable effect on PR prices. In fact, after having spiked at \$ 430/t the PR price fell to about twice the pre-spike level of \$ 90/t, the price of PR rose again further to another price peak of \$ 202 in late 2011-early 2012 (Heckenmüller et al, 2014). The perceived sudden abundance of PR reserves did not halt this development.</p> <p>In recent literature, it has been repeatedly argued that the PR market currently is driven by various supply and demand side factors and that historically, the price of PR has been closely related to prices of food and other agricultural commodities, as was also the case in the 2007/2008 price spike (Van Kauwenbergh, 2010). A reason for this may be that fertilizer investments rise when food prices rise (Heckenmüller et al, 2014). The downward price revision that occurred after 2012 has been associated with the gradually expanding mining capacity which followed the 2007/2008 price spike (Heckenmüller et al, 2014). Indeed,</p> |

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| | <p><i>as PR and its derivatives that increasing the stated reserve base would cause market volatility or correction and hence harm the fragile economies which depend on them. Several such market corrections have been experienced since mineral prices peaked in 2008."</i></p> | <p>given the high capital costs for PR mines and the time it takes to get a mine operational (Van Kauwenbergh, 2010), it would appear that mining capacity is more limiting to PR supply than the PR in situ ore that could be mined. For the near future, PR prices are expected to remain relatively stable, which may be due to the expanded PR production capacity (Heckenmüller et al, 2014).</p> <p>The reviewer states that data on water resources is commonly withheld for 'similar reasons'. Water, however, is an altogether different resource where countries may have conflicting interests relating to the same resources. Without further explanation or source being provided, it is not clear why the analogy would hold.</p> <p>While these economic observations are very interesting, they are beyond the scope of our research questions.</p> |
| E.4.a | <p><i>"This recent period of volatility is likely to continue and throws into question another key premise on which the authors base their case. They argue "that the reserve base was created to mitigate the effect of fluctuating prices which impacts, or should impact, the reserves even more than the reserve base (USGS, 1982)." This may have been true thirty years ago when the US totally dominated the PR market, during which time it was arguably in its national commercial interest to reduce volatility and protect its national farming industry. But this quasi monopolistic control is no longer the case, power and market share having being wrested away by other producers, while the US industry is now consolidating through mergers and acquisitions."</i></p> | <p>As already discussed in our response to the second review (see supplement to second review, cell C4.6) our comment on the reserve base referred to in the left hand column is a sidestep in our findings relating to IFDC's definitional simplification and by no means "a key premise" in our research. Our main comment to IFDC's definitional simplification was that discarding any granulation and reducing the applied resource terminology to two largely undefined classes (reserves and resources) would result in inherently vague and incomparable data. In our response to the second review, we noted that Messrs. Scholz and Wellmer did not discuss this finding at all. Instead, they focused entirely the same single comment on the reserve base, which was that IFDC's argument to discard the reserve base (clear monetary thresholds are required for the reserve base, which require continuous updating) applies <i>a fortiori</i> to reserves. We also indicated that, in the final version of the paper, we will delete our statement on the reserve base in order not to distract the focus from our main comments.</p> <p>Meanwhile, we have some difficulty following the reviewer's logic in respect of the reserve base. The reserve base is part of the general resource classification which applies to all minerals (USGS, 1980). The reserve base was introduced to create a more stable basket of PR ore that would be less subject to fluctuation than reserves and hence provide a more robust basis for long term planning. The fact that the United States are currently less dominant in the PR market than they used to be in the early eighties, does not discard the logic behind reporting a reserve base. As pointed out in the second review, the reason why USGS stopped reporting a reserve base for all commodities is that its budget was cut and that it apparently lacks the funding to engage in more detailed reporting of global commodities.</p> |
| E.5 | <p>Nr. 5. <i>"Large resource hungry countries such as China will guard their PR resources as a strategic resource and hence not disclose quantities available or tenor."</i></p> | <p>This may be the case. However, even if certain producing countries would have their incentives not to share data on reserves and resources this is not an argument to lower standards for data on reserves and resources. We refer to our general response to the fourth review. Once again, this comment lies beyond the scope of our research questions.</p> |

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| E.6 | Nr. 6. <i>"As well as the commercial risk to a producing country of full disclosure of resources and reserves, the global trend in the PR industry is to sell value-add products such as acid and fertiliser not rock. This further reduces the appetite of key producers to declare what resources they command. Some countries, for example Indonesia, have now made the export of raw minerals illegal, export only being allowed for value-add product."</i> | The reviewer does not explain why a shift to more value added product would reduce the appetite to report mineral resources. Again, this observation lies outside the scope of our research questions. |
| E.7 | Nr. 7. <i>"New technologies are rapidly emerging for processing lower value ores. Hence what has traditionally been regarded as a BPL value of 70 as the standard for selling PR on the commodity market is likely to fall in future perhaps even into the 50s."</i> | <p>The reviewer's comments 7 up to and including comment 11 essentially deal with the same issue: reserves and resources are dynamic due to technological and economic developments, new discoveries and shifts in political and social circumstances.</p> <p>In our paper, we described these dynamics, which are well recognized in USGS and USBM (1982), UNFC (2013) and other classification documents. While such developments may call for amendments of the threshold category for reserves and other resource categories, they do not appear to imply a direct cause for PR producers not to "disclose their hands" or to impair a proper reporting of reserves and resources.</p> |
| E.8 | Nr. 8. The reviewer states that new techniques are making it possible to work deposits with lower contents as well as revisiting of mine tailings, which will increase reserves. | We have discussed this in our paper. |
| E.9 | Nr. 9. The reviewer argues that offshore mining may lead to recognition of reserves and resources which are currently not recognized as such. | <p>In our paper, we have discussed that offshore deposits exist and that their exploitation may be or become feasible. While a number of large deposits have been described in general terms in the older literature, information on these deposits and their potential is hard to obtain. This stresses the need for further research on these deposits and their potential.</p> <p>We repeat our comments in column 7 above.</p> |
| E.10 | Nr. 10. <i>"In Europe improved exploration and analytical techniques are predicting major reappraisals of the state of resources and reserves of a wide range of "critical" or "essential" minerals, especially in countries previously thought to be mined out. The ERA-MIN network, of which I have been part, estimates an increase of some 50% in resource quantification by these means. The more policies of national or regional self-sufficiency in mineral</i> | We repeat our comments in column 7 above. |

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| | <i>supply are pursued – and the EU looks to be intent on pursuing them – the more such resources will become reserves. Criticality factors will therefore, progressively be included in the definition of “reserve”, even when the economics as referenced to international costing benchmarks are not viable."</i> | |
| E.11 | Nr. 11. <i>" New on-shore deposits are being discovered all the time as many emerging economies start significant geological survey and exploration activity across a wide spectrum of mineral and oil and gas resources. Many such countries have little or no data as yet; and where data does exist it tends to be from the end of the British or French colonial periods"</i> | <p>We repeat our comments in column 7 above.</p> <p>In addition, we refer to comments C.1.3 (page 6) and C.3.4 (page 12) of the supplement to our response to the second review, and in particular to the following observation by Van Kauwenbergh, 2006, considering the potential for discovery of new deposits:</p> <p><i>"There is also the potential to discover new deposits. However, oil exploration programs have explored most of the coastal sedimentary basins of the world during the past 20-30 years, and any large-scale discoveries of phosphate rock probably would have occurred in conjunction with these activities."</i></p> <p>In our paper, we also referred to a statement by USGS that the discovery of major new deposits is considered unlikely. When discussing these newly discovered on-shore deposits , it would be interesting to know their size and potential. After all, as we noted in our response to the second review, the term "deposit" is not very informative and may include minor deposits of low grade with little relevance (see: comment C.7.2 page 22 of the supplement to our response to the second review). We also note that, when new reserves or reserves are being reported, this does not always signify a discovery, as testified by the Iraq example discussed in our paper. A more interesting question is not whether "new" reserves and resources are being presented from time to time, but the rate at which genuine discoveries are being made, in comparison to the historic discovery rate. As far as we have seen, there is no analysis available of the historical global discovery rate of PR. This seems an interesting area for further research.</p> <p>The reviewer states that, where data exists, it tends to be from the colonial era. For completeness, we note that, information on PR deposits is also sometimes generated in the context of development aid. For instance, in Sub-Saharan Africa, there are many small known deposits of PR which are currently not being exploited for various reasons. Part of these deposits been examined and valued in the context of development aid projects, by government organizations as well as private firms in order to assess their potential to provide PR products for the African market (Killiches, 2013, with reference to Van Kauwenbergh et al. 1991) , of which no copy could be obtained).</p> |
| E.12 | Nr. 12. <i>"As the concept of the “social licence to operate” gains more and more ground, it is clear that even when resources and reserves are accurately and</i> | The value of having a more comprehensive set of data on reserves and resources for the purpose of longer term resource management is among the rationales behind the USGS and the UNFC classifications and is recognized in a large number of publications including the IFDC report, UNEP's 2011 year book (UNEP, |

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| | <i>transparently calculated and reported, as for example in Florida, resistance to mining, of any kind, can put resource progression into reverse. Such evidence of the "social licence to operate" being withdrawn not for economic but political reasons, further puts in question the value to "societal" decision-making of abstract data, however accurate."</i> | 2011) Van Vuuren et al. 2010, Vaccari and Strigul (2011) and others. As the reviewer states, reserves may be downgraded due to social opposition or legal impediments. However, this does not exclude the possibility that such deposits may be upgraded to reserves again as legal, regulatory and other criteria evolve over time (Van Kauwenbergh, 2010). Indeed, the kind of inverse resource progression as described here by the reviewer does not indicate that the data concerning these deposits have lost their relevance from a long term planning perspective and could not be reported in accordance with their limitations. |
| E.13 | Nr. 13. Under point 13, the reviewer discusses that recycling of human waste is currently not accepted by consumers | While of interest, this comment does not relate to the difficulty of obtaining reliable reserve data or the (un)willingness of PR producers to accurately report these. We agree that it would be most desirable if more recycling could take place. |
| F | <i>"With these and other factors in play, it becomes less and less likely that the major PR producers will disclose their hands, especially where the production base is financed through the world's stock exchanges or belongs to state-owned companies which are principally interested in food security or national self-sufficiency in food."</i> | We refer to our comments to the reviewer's points 1-13 above as well as to the general response to the fourth review. |
| G | <i>"The authors seem intent on adopting a tone of moral indignation with perhaps the intention to shame PR producers into disclosure of the reserves and resources they hold. Will this work In view of the many factors involved in this issue?"</i> | In our paper, we have analyzed findings by IFDC, a non-governmental organisation located in the USA. In addition, we have analyzed reports of PR reserves and resources by USGS, a US government organization and many other documents from various sources. We found that there is much confusion surrounding data on PR deposits. However, we did not criticize any PR producers or producing countries for any perceived lack of disclosure. The point that we made was that, if data are being generated in order to fuel the scientific debate or inform policymakers, these data should be reliable and comparable. |
| H | <i>"In the first place, they seem to be courting controversy for its own sake. The opening sentence of the abstract describes "Phosphate rock (PR)" [as] a finite mineral indispensable for fertilizer production and a major pollutant". The wording suggesting that PR is inherently polluting is clearly incorrect, and for reasons that are not clear the claim is not substantiated. The authors seem to have forgotten the classic observation of Paracelsus "Alle Ding' sind Gift, und nichts ohn' Gift; allein die Dosis macht, daß ein Ding kein Gift ist" Any mineral can be a pollutant if you apply too high a dose. PR is not a</i> | The reviewer submits that we are courting controversy for its own sake by indicating that PR may be a potent pollutant if applied in excess. The pollution that can be caused by phosphates when applied or discharged in excess are generally accepted and well described in a large and ever expanding body of scientific literature. In a footnote to the original paper, we devoted the following comment to P pollution: <i>"Human use quadrupled the natural flows of P into the environment since pre-industrial times, resulting in massive eutrophication of the freshwater environment. It is argued that this increased flow is unsustainable and that the global boundary for P has been transgressed substantially (Carpenter and Bennet, 2011). This pollution aspect of P, though very important, will not be discussed in this paper. In determining the sustainability of the P cycle, this aspect should, obviously, be taken into consideration."</i> |

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| | <p><i>major pollutant as such; but bad practices along the PR value chain can cause pollution. The opening lapse into confusing the inherent properties of minerals with the way people use them is echoed in the indignation addressed to Steve van Kauwenbergh as author of the IFDC 2010 report (Van Kauwenbergh, 2010). It is as if the authors feel offended by the degree to which PR has made us dependent on it, (“indispensable”). Is this a sensible basis on which to conduct a reasoned appraisal of the very significant geological, taxonomic, economic, social and environmental challenges posed by trying to classify and quantify any resource from the geological endowment, whether phosphate or oil and gas resources and do so in a transparent, comprehensible manner?”</i></p> | <p>The line now singled out by the reviewer was included to indicate that P pollution is another key issue in the P debate, in addition to concerns of long term PR scarcity. In the introduction of the paper, we indicated that the IFDC report appeared to have shifted emphasis from the depletion angle to the pollution angle of P.</p> <p>We do not think that we have stated anything unusual or controversial. However, having reviewed this sentence, we think this line would be clearer if amended as follows:</p> <p><i>Phosphate rock (PR) is a finite mineral indispensable for fertilizer production, while P is a major pollutant when applied or discharged in excess and a cause of widespread eutrophication.</i></p> <p>We will make this change in the final version of the paper.</p> |
| I | <p><i>“The authors further argue: “Given the near total dependence of food production on PR, data on PR deposits must be transparent, comparable, reliable and credible.” “Must” by whose reckoning? And is food production in a state of “total dependence” on PR? Is the critical issue for the future “food production” or “food security”. It is clearly the case that since the end of WWII the emphasis has been on production; but this is changing fast.”</i></p> | <p>Our paper contains references to UNFC (2010) which states that in order to be compatible with UNFC, classifications need to meet requirements of relevance, materiality, reliability and comparability. We also pointed at Scholz and Wellmer (2013) who used the terms cited in the left hand column in the context that reliable predictions and modeling about reserves dynamics require reliable data. However, there are no mandatory global requirements in this respect. We will amend "must" in "should".</p> <p>The manner in which the industrialized world grew dependent on inputs of P and other nutrients has been described in numerous publications (For instance, Cordell et al. 2009, Schröder et al, 2010, Hilton and Dawson, 2011). In Hilton and Dawson (2011) the reviewer described how population pressure in Great Britain resulted in declining soil fertility and concluded that, had the commercial manufacturing process for phosphatic fertilizer not been discovered in the 1840's, life in the UK and other industrialized countries would have become unsustainable. The authors also stressed that the global population which was threatened by a lack of soil fertility was less than 1.5 billion, while population may grow to 9.2 billion by 2050, "all of whom will depend on a sustainable solution to the supply of nutrients to soils to replace those removed at harvest." The high yields of the green revolution depended on the "technological trinity" of NPK fertilizers, water and seeds (Van Kauwenbergh, 2006) and the countries where it occurred (including China, India, Indonesia) are no less fertilizer dependent today. It is argued that a second green revolution is necessary in sub-Saharan Africa and South-East Asia where decades of soil mining (i.e. continuous cropping without sufficient inputs of P and other nutrients) have resulted in severe nutrient depletion and agriculture is less and less able to feed a growing population. Fertilizers are viewed as a major part of the main solution (Quinones et al, 1997, African Union, 2006). The number of persons that could theoretically be sustainably fed without mineral additions of N, P, K and other nutrients depends on a large number of factors including food chain and agricultural efficiency, the use of organic sources, recycling, and dietary preferences (phosphorus intensive meat and dairy versus a less intensive approach). However, the current</p> |

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| | | <p>reality is that PR fertilizers are the primary source of P inputs into agricultural land (Killiches, 2013); that modern mechanized agriculture is highly dependent on it to maintain soil P level at productive levels (Schröder et al., 2010) and that current levels of food production could not be produced without processed mineral fertilizer (Cordell et al. 2009). We will change "near total dependency" in "high dependency".</p> <p>In the context of PR availability, food production and food security are directly related. If PR scarcity occurs at some point in the future, this will impair the ability to produce food and, in consequence, food security. We do not consider it useful to elaborate on this difference further in the context of our paper.</p> |
| J | <p><i>"The context in which the IFDC Report was published was in effect as a response, following a small piece in Nature (Gilbert 2009), to almost apocalyptic fears that the world's phosphate reserves were about to run out (Cordell et al 2009). An analogy was argued between peak oil and peak phosphorus, and the peak phosphorus issue has caused much confusion and discussion. Some, including myself, argued that the analogy did not hold at all (Hilton et al 2010, Dawson and Hilton, 2011); more recently the theory of peak oil itself has been challenged, further weakening the basis on which the quantitative estimates were based. In this reviewer's opinion all that Steve van Kauwenbergh has done is to use his best interpretation of the data that was available to him to indicate that there is no "peak phosphorus" event current, or imminent. Very importantly, he [Van Kauwenbergh] has been equally clear that the basis on which the great majority of data about phosphate resources and reserves is founded is open to considerable question and doubt. The 2010 IFDC Report makes frequent reference to its provisional nature and argues: "A collaborative effort by phosphate rock producers, government agencies, international organisations and academia will be required to make a more definitive current estimate of world phosphate rock reserves and resources". So has the Report "thoroughly shaped the PR depletion debate"? In my experience the debate is not that coherent."</i></p> | <p>In our paper, we discussed that the IFDC report was published in response to concerns over PR depletion and a number of papers which attempted to calculate the timeframe in which peak phosphorus could occur. The reviewer states that all IFDC has done, is to use his best interpretation of available data to indicate that no peak P was imminent and that IFDC has been clear that the great majority of PR data are open to considerable doubt.</p> <p>Indeed, the IFDC report states that many assessments are open to question and that the terms "reserve" and "resource" are not used consistently on a worldwide basis. The IFDC report states, on p. 18: <i>"It cannot be stressed enough that only a fraction of the phosphate rock resources are technically and economically suitable for production at any point in time. Technology changes and product in costs fluctuate over time."</i></p> <p>However, no such reservations were made when Gharbi's estimate of "reserves" were integrally accepted as in situ ore reserves for three of Morocco's four main PR deposits. As we pointed out in our paper, the same deposits were reported numerous times as resources in OCP public statements (the latest of which OCP, 2000) and in Gharbi and M'chichi (1996). In a previous paper discussing Gharbi (1998), IFDC, likewise, acknowledged that the word "resources" would probably have been more appropriate in the Gharbi estimate (Van Kauwenbergh 2006). Again, none of this was conveyed in the IFDC report.</p> <p>The reviewer doubts whether the IFDC report has profoundly influenced the PR depletion debate. The reports' impact is evident in our view. USGS increased Moroccan reserves with a factor 10 based, inter alia, on the IFDC report and the new reserve numbers by IFDC and USGS are widely used as a benchmark in the literature. The findings in the report have triggered conclusions in the scientific literature that currently recognized PR reserves have a (static) lifetime of hundreds (Van Kauwenbergh, 2010, Scholz and Wellmer, 2013) to thousands of years (Vaccari and Strigul, 2011). Some of these conclusions were repeated in reports by environmental organizations (Tirado and Allsopp, 2012) and UNEP's year book for 2011 (UNEP, 2011). The recent Consultative Communication on the Sustainable Use of Phosphorus by the European Commission (EC 2013) and the in-depth report on sustainable phosphorus use by the EC's Directorate General for the environment (EC Science Communication Unit, 2013) both explicitly name the IFDC report and the subsequent USGS MCS as currently the only available data sources on global PR reserves. The increase of the RC ratio, based on the IFDC/USGS updates, has been used in the second review of this</p> |

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| | | <p>paper to conclude that "humanity is on the safe side". Comparable comments have been made in Global TraPs' response to the EC's Consultative Communication (Scholz and Roy, 2013; see the general response to this fourth review . We think it is evident that the report profoundly influenced the debate, as acknowledged also by the first reviewer.</p> <p>IN our view, it is also evident that the data presented in the IFDC report and USGS are in need of independent vetting.</p> <p>As stated in our paper, we very much welcome a collaborative effort to make a more definitive estimate of reserves and resources, including those deposits which may become a reserve or resource in the future. However, the current reality appears to be that no such research project is envisaged.</p> |
| K | <p>UNFC</p> <p><i>The authors take IFDC to task for “simplification”: “IFDC’s simplification appears at odds with this gradual global movement toward uniform resource reporting.” They have clearly not understood that the whole point of the UNFC EFG axes and the simple numerical resource progression coding that goes with them is to simplify.</i></p> | <p>The reviewer appears to be comparing apples with oranges. In our paper, we described that in 2009, the UNFC was simplified and amended in order to align it with the CRIRSCO template and the Petroleum Resource Management System designed by the Society of Petroleum Engineers (SPE). We indicated that the UNFC still incorporates a detailed granulation which makes it particularly suited for long term inventory purposes as the code allows coverage of all types of mineral occurrences at their specific stages of feasibility and geologic certainty of existence, regardless of their current economic potential. Therefore, though simplified, the UNFC offers rather precise instruments to record deposits according to their potential and does not sacrifice completeness. See also UNFC 2010, page 1:</p> <p><i>The UNFC-2009 is a strong code, offering simplicity without sacrificing completeness or flexibility. It paves the way for improved global communication which will aid stability and security of supplies, governed by fewer and more widely understood rules and guidelines. The efficiencies to be gained through the use of UNFC-2009 are substantial.</i></p> <p>The IFDC report, in contrast, reduces PR reserve reporting to two classes. It proposes to report reserves as "Phosphate rock that can be economically produced at the time of the determination using existing technology; reported as tons of recoverable concentrate" and resources as "phosphate rock of any grade, including reserves, that may be produced at some time in the future; reported as tonnage and grade in situ". Unlike the USGS, CRIRISCO, JORC and UNFC classifications, this simplified terminology contains no economic requirements or thresholds in view of the degree of geologic requirements. We concluded that this lack of granularity makes it difficult to compare data with those under leading classifications. Neither the second nor the fourth review contains any discussion on these findings.</p> |
| L | <p>A solution?</p> <p><i>It is unlikely that the many issues around getting reliable estimates of the world’s economically recoverable phosphate reserves will be resolved in the foreseeable future but there are important opportunities that involve</i></p> | <p>We discussed this comment in our general response to the fourth review. We refer to the section under the header: Reliable data on PR reserves and resources – part of the solution?</p> |

all stakeholders for using phosphorus more efficiently in agriculture and thus lengthening the life of the existing reserve.

The solution to the phosphate management challenge is for all of us to realise that it can be managed as a near closed cycle. Industry (supply-side) has to markedly improve the efficiency of mining and beneficiation in the primary processing segment of the cycle, and engage fully in the recycling segment whether from wastewater, food processing plants or biosolids. There are encouraging signs, as for example in Berlin and in a number of Dutch cities, that recycling is beginning to happen. The demand segment of the overall cycle must increase as population increases. However, our collective behaviour, and perhaps societal choices to change our behaviours in relation to the quantity and type of food we consume, on human health, especially obesity and the type-2 diabetes epidemic, requires attention. We have done it with drinking and driving; we are doing it with waste reduction and prevention; so maybe we can do it with food.

And the supply-chain also has its part to play. The Economists in the UK Government Foresight Study [UK Foresight Report, 2011] point out that a 150year cycle during which food costs as a proportion of household income steadily declined has ended; food prices are going to go up from now on. The other major segment of the overall P cycle is in the soil where it is managed by farmers who must (re)learn the basics of managing soils, whether to safeguard their physical condition or to optimise the fertility of their soils by applying the right nutrients, in the right form, at the right time and in the right quantities, just as Paracelsus would have asked. They can do so in the knowledge that, contrary to the prevailing opinion up to 2008 that PR once put onto land in the form of mineral fertiliser was part of an essentially open system - P either got locked into the soil, or ran off

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| <p><i>into water courses and hence became “a major pollutant” - in fact in their FAO Study (Syers, Johnston, Curtin, 2008) the authors showed that the P system was largely closed and could hence be efficiently managed. The fulcrum is the critical P value which must be maintained for any soil, a value which is established by accurate soil and crop data, and which is sustained by the Paracelsan mechanism of dose control. Speaking at one of the Global TraPs meetings, Zurich August 2012, Terry Roberts cited this work as now the reference for all analysis of the management of P in soils, indicating his agreement with a paper I published with IFS (Hilton 2010) that this was the real game changer. Given that soil fertility can be demonstrably shown to be a managed and manageable outcome, the real issue for the sustainability of P resources and reserves is efficient management, across the whole value chain. This includes both primary and secondary P.</i></p> | |
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