

Interactive comment on “Field-based groundwater recharge and leakage estimations in a semi-arid Eastern Mediterranean karst catchment, Wadi Natuf, West Bank” by Clemens Messerschmid et al.

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Answers by: [C. Messerschmid, J. Lange and M. Sauter \(18 October 2018\)](#)

Review:

Field-based groundwater recharge and leakage estimations in a semi-arid Eastern Mediterranean karst catchment, Wadi Natuf, West Bank; Messerschmid et al.

I have mixed feelings about this paper. In principle the broader background problem/issue (spatial/temporal recharge estimation of semi-arid mountainous areas) of this paper is interesting and important. Water management in the study area is also a big issue, hence the topic of the paper is good. Further, it is commendable that this paper aims and is based on extensively collected field data.

However, the introduction, presentation of the data, methods, results is far from mature. The paper needs a big overhaul of its structure (i.e. where in the paper is presented what), the logic and analysis support, and finally a detailed and broader discussion linking it to state of research in this field of research.

[Thank you very much, estimated Prof. Batelaan, for the time you invested and for your constructive review and comments that are very helpful to process the manuscript.](#)

[We do understand that some of the passages are difficult to follow. This is however also a matter of the subject, i.e. the complex recharge mechanisms in a spatially distributed parameter field, in a semi-arid climate, with rapid recharge and complex runoff processes.](#)

[Here we shall address your comments and restructure our manuscript for better legibility. We shall thoroughly revise the state of the art section; provide a new paragraph and graphics illustrating our methodological approach and concept of data analysis.](#)

I got several times confused or could not follow the argumentation, a lot of work will have to go into making the text a lot more clearer.

[We shall provide a conceptual diagram illustrating our understanding of the recharge mechanism in the area and a flow diagram of the different work steps, data analysis, modelling procedures and calculations.](#)

Moreover, the used terminology is often not very precise. It is difficult from the many tables to grasp the significant points. The figures and the captions could be improved, potentially more figures instead of tables could help to clarify the paper.

[We shall follow your advice. Some of the terminology is a result of the complex recharge mechanism, the different disciplines involved \(hydrology, hydrogeology, geology\) and the specifics of the region.](#)

I have provided in an attached marked up version of the paper many more general and detailed comments.

Thank you very much for your efforts. This is very helpful.

Please also note the supplement to this comment:

<https://www.hydrol-earth-syst-sci-discuss.net/hess-2018-329/hess-2018-329-RC3-supplement.pdf>

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2018-329>, 2018.

Comments hess-2018-329-RC3-supplement.pdf

Page: 1

No.#1 not clear from the title what this is, i.e. vague

We shall reformulate the title and unambiguously. The new title is now:

Spatial variations of groundwater recharge in a Mediterranean leaky karst aquifer system – parsimonious modelling and field-based estimations in Wadi Natuf, West Bank.

Page: 2

No.# 1 unclear

This passage will be reformulated. (We wanted to express that simulated recharge periods were compared to the temporal patterns of spring hydrographs.)

No.# 3 vague, unclear. Moreover, an aquitard is by definition 'leaky'

Thank you, we shall work on the terminology and introduce the concepts early in the article – such as here: aquitards and aquicludes.

(Strictly speaking, there is no such thing as pure “aquicludes” in nature. However, in this region, the term is often used and attributed to some of the formations we study. Therefore we shall define “aquicludes” here as formations with no or negligible leakage, whereas “aquitards” shall be defined as formations that allow significant and measurable amounts of downward leakage from the aquifer formations above.)

Page: 3

No.# 1 I strongly have the feel that the Introduction needs some restructuring. It does not have a logical structure. It starts too specific - detailed.

Thank you. Yes, we shall rewrite the Introduction (and Methodology) with special emphasis on the flow of arguments. We have been working on this issue already, i.e. to illustrate the objectives, methodological approach, as well as the data evaluation in a more concise way

-What is the bigger picture problem here? Who has worked on it and what is not solved? The literature has not been optimally used for this.

cm: Thank you for the comment; we shall revise the manuscript thoroughly.

-You are going to work on that scientific gap/problem in more detail in a specific area. What is the general characteristics of this area? You already need a figure to support this.

Thank you for the comment; we shall revise the manuscript thoroughly. We shall try to stick to the general features here and otherwise refer to the appropriate section under chapter 2. Area (“as will be outlined in the description of the study area, ...”).

-What is problem in this area; this leads to a specific hypothesis with a scientific question. A schematic figure could help in making this clear (I imagine something with a cross-section with the deeper aquifers in it but also the hill-slopes with there perched aquifers, underlying aquitards; arrows (?) for recharge and leakage processes.

Thank you for the comment. You are correct. We shall insert a conceptual diagram that explains some of the processes (and terminology) used in the article. Otherwise, more detail will be given in Ch. 3. Methodology.

In your writing, especially terminology, you should also try to be more accurate, many sentences seem vague or use a series of words which confuse.

Thank you for the comment; we shall revise the manuscript in this respect (introduce a conceptual diagram and references to the literature).

No.# 2 Why a range?

Thank you for your comment. We shall clarify that different definitions of the boundary conditions and area size of the basin exist in the literature (especially with respect to the area south of the Afiq channel near Gaza, and with the Sinai portion of the WAB...)

No.# 4 vague, please be more specific

Thank you for this comment. Yes, indeed, we can be more specific: The WAB with a current average use of 389 mcm/a provides 18.261% of total Israeli bluewater production (from wells, springs and surface water Palestinians enjoy only a 6 %-share in basin abstractions.

No.# 5 what do you mean by 'intermediate local'? Better not to use such descriptions.

Thank you. We will introduce the concept of the local perched aquifers more thoroughly. Here, in the introduction we will give a general characterisation and otherwise refer to the details under Ch. 2 Area and 3. Methodology. (We will avoid the misleading term 'intermediate' for the aquifers positioned between the Upper and Lower regional aquifers.

No.# 7 aquitard are leaky by definition. 'leaky aquifers'?

The aquifers overlying aquitards are defined as 'leaky'. The springs in the perched aquifers are contact springs. However, you are right, they are not fed by the aquitards but by the leaky perched aquifers above.

No.# 8 Normally the first fig should be Fig. 1. What is Ch. 4 referring to?

Thank you for your comment. We shall take out the reference to this figure. Thus all figures will be first mentioned in order of their numbers.

No.# 11 why 'intermediate'

Thank you for your comment. We shall produce a conceptual diagram that demonstrates the system characteristics, and properly describe the in the text. More details will be found in Ch. 2 Area.

No.# 13 Not clear what that is without a proper geological description

Thank you. We shall try to only refer to general features here and discuss the details – like regional aquitards according to the nomenclature – in Ch. 2.

No.# 15 not clear what that is, needs explanation.

Thank you we, will duly introduce and reference this term (“effective precipitation” or HEP, “hydraulically effective precipitation”).

No.# 16 Where is this? The area is not introduced, refer to a map?

Thank you for this comment. This was helpful. We shall refer to Fig.1 (under the current numbering system).

No.# 19 water

Thank you for this comment, we shall insert the word 'groundwater'.

No.# 21 vague

Yes, thank you for this comment. We shall give a more detailed description of Radulovic's methods.

No.# 22 not clear what this refers to

Thank you. We shall clarify: “to understand these recharge processes conceptually”

No.# 25 'Recharge infiltration' is not a good term. 'recharge' and 'infiltration' are different processes.

Thank you. You are right. We shall work on the terminology, as stated above. Introduce our terms more properly in the beginning and stick to them throughout the article.

(We define infiltration as transition of water into the soil, whereas deep percolation stands for the movement of soil water beyond the root zone and soil layers into the bedrock (usually the unsaturated zone. This deep percolation constitutes 'potential recharge' as the water has not yet entered the water table in the aquifer, which would be 'actual recharge'.)

No.# 1 not explained before

Thank you. We shall explain RC (Runoff coefficient) upon first mentioning.

No.# 3 'landform' is not appropriate as a description for LU/LC change

Thank you for the comment. You are correct. We will refer to LU/LC instead of 'landforms'. (Much of the area is not under use, so the term will stress more on natural topographic features like relief and natural vegetation than on anthropogenic features such as agriculture and other land use.)

No.# 7 in this area? or in general? The last would not be correct.

Thank you for this comment. Indeed we were referring to the study area, or wider area (like the WAB and Dead Sea environs).

No.# 9 you mean probably something like 'annual estimation methods'.

Thank you, yes, we shall replace the term.

No.# 10 in the case of

Thank you. We shall reformulate this.

No.# 11 this sentence needs rephrasing, too complex. What is 'temporal distribution pulse', i.e. not well defined.

Thank you for the comment. You are correct. We shall see to that.

No.# 13 s

Thank you, we shall correct this.

No.# 14 do you really mean accuracy? From what follows it seems not.

Thank you for the comment. You are correct. Abusaadah probably also meant 'reliability'. (However, when he stresses the need for data refinement, he also refers to accuracy.)

No.# 1 [he deleted: "and aquitards"]

Yes, thank you. Of course, Peleg & Gvirtzman try to understand processes within the aquifer. However, in their text, they also stress the pivotal role of the aquitards beneath: "*Perched springs in nature emerge from aquifers laying on aquitards within the unsaturated zone*"

No.# 2 of

Thank you, we shall correct this.

No.# 3 by

Thank you, we shall correct this.

No.# 4 what do you want to say with this?

Thank you for the comment; we shall explain this quote more thoroughly: Two exceptions stand out. Peleg & Gvirtzman (2010) and Weiss & Gvirtzman (2007) studied recharge in perched local aquifers and aquitards on small-scale erosionally isolated groundwater catchments, using spring discharge⁴ from these units and applying it to numerical models, however, without accounting for downward leakage in the multi-layer systems or explicitly excluding such leakage "*by treating the bottom unsaturated layer as if it is saturated*" (Weiss & Gvirtzman, 2007).

No.# 6 aquitard

Thank you for the comment; Yes, into the underlying aquitard (*through the bottom of the perched aquifer...*)

No.# 6 [deleted: "generation"]

Thank you for the comment; we shall revise the manuscript thoroughly.

No.# 8 How much? Which station, years?

Thank you for the comment; we shall revise the manuscript thoroughly.

No.# 10 Start your study area description with this type of more general description

Yes, thank you. We shall see to that.

No.# 1 F

Thank you for the comment; you are correct. We shall revise the manuscript accordingly.

No.# 2 You jump in the order of your Tables. Provide the tables in the order that you reference them.

Thank you very much for the comment. In the final paper, the tables will be inserted IN the text at the appropriate location. We shall make sure that we adhere to the appropriate order of the tables.

No.# 3 exceptional: I think you mean something else

Thank you for the comment; we want to describe the sparse occurrence of coniferous forested areas

No.# 6 You only very roughly, descriptive, show that there is a correlation; too base on that a conclusion that you can regionalize the recharge is too strong.

Thank you. We will revise the manuscript thoroughly and explain this in more detail. In addition, we shall add references to already published papers...

No.# 1 better 'recharge area'

Thank you, we shall change this into "recharge catchment areas".

No.# 4 what do you mean?

Yes, thank you; the procedure of key date measurements at the springs shall be explained more thoroughly, together with visual material (graphs or tables).

No.# 7 unclear

Thank you for the comment; we shall revise the manuscript thoroughly and explain the procedure in more detail.

No.# 9 rephrase

See above...

No.# 12 why?

See above...

No.# 15 not explained before

Thank you for the comment. You are correct. We shall explain abbreviations upon first mentioning.

No.# 16 a data record of 13 years of ...

Thank you for the comment. We shall revise this and make clear that we do not speak of 13 years of measurements, but of a set of 13 SM-measurements.

No.# 19 a time resolution of half-hour.

Thank you. We shall revise this.

No.# 23 no footnotes, include or do not include it in the text

Thank you for the comment; we shall revise the manuscript and insert this list into the main text.

No.# 2 The ranking procedure is not clear

Thank you for the comment; we shall revise the manuscript thoroughly over this point. We will present our work differently and also using a different terminology.

No.# 3 have

Thank you; we shall revise the script.

No.# 1 I lose you in this paragraph, I cannot follow well the methodology, correlation, scenarios, etc.

Thank you for the comment; we shall revise the manuscript accordingly and shall change the terminology ('ranking', 'correlation', 'scenarios', etc.). We shall also revise our tables and graphs accordingly.

No.# 1 This is really a results and discussion section. I would strongly suggest to separate the results and discussion in order to get a clearer presentation and better discussion (strength-weaknesses of approach, comparison with other studies, upscaling, etc)

Thank you for the comment; we shall revise the manuscript accordingly. We might actually change the entire structure and add a chapter on Discussion.

No.# 4 should be quantified

Thank you for the comment. You are correct. We shall see to that and discuss the quantitative findings of Figure 4 in the text.

No.# 7 should be quantified

Thank you for the comment. You are correct. Again, we shall quantify the findings in the text.

No.# 9 quantify

Thank you for the comment. Again, we shall present these quantifications in the text as well.

No.# 2 This is a method description and does not belong in the results section.

Thank you for the comment; we shall revise the manuscript and structure thoroughly. The description will move to the Method section.

No.# 2 This is more a method description and is partly a repetition of earlier explanations.

Thank you for the comment; as above, we shall revise the manuscript and structure thoroughly. The description will move to the Method section.

No.# 1 You should discuss this

Thank you for the comment; we shall revise the manuscript and structure thoroughly. We shall already discuss some the concept of the leaky aquifers in Ch. 1. Introduction (together with a conceptual model graph) and in Ch. 3. Methodology.

No.# 3 rephrase sentence

Thank you; we shall rephrase the sentence: "The study demonstrated that it is possible to apply empirical approaches based on field-measurements in order to estimate spatially differentiated recharge in the Western Aquifer Basin."

No.# 1 What is the difference between the first two lines?

Thank you. We shall explain that the 1st line is number of years (#), while the 2nd line refers to the period of recording

No.# 2 abbreviations should be explained in the caption. Are the values averages for the years measured?

Thank you. You are correct. We shall write extended captions (and we shall keep the abbreviations to a minimum and explain them properly). We shall also modify the table as follows:

- No, the values do not show the averages; instead they present stable physical soil properties that remained unchanged throughout the measurement period (such as for example installation depth of sensors).
- In the case of "SM peak", we hereby present the absolute maximum recorded SM.
- As suggested by the other reviewers, we will change the term "WP" and instead use "minimum SM". This is because they rightly remarked that SM_{min} is not always equal to WP. It should be noted that both, FC and SM_{min} , are absolute values, which remained stable over the years.

No.# 2 This should be table 2

Thank you. You are correct. We shall revise the table numbering.

No.# 2 not clear what these are

Thank you. We shall explain in the captions (and in Ch. 3. Methodology) that these abbreviations refer to rainfall sub-catchments.

No.# 4 avg?

Thank you. As already noted, we shall revise and keep abbreviations to a minimum – and replace them by words (such as this symbol for average)

No.# 1 unclear

Thank you for your comment. As already noted above, we shall modify our procedure and terminology such as for “ranking”, “scenarios”, etc. This will be explained in both, the manuscript and the Table captions.

The captions (and Methodology) will also note and explain that Wadi Natuf surface catchment extends over two groundwater basins and that this table refers to all of the Natuf surface catchment, therefore covers parts of both basins (WAB and EAB) - see also map Figure 1b.

No.# 1 Why this order of alternatives? Why vertical line between Alt.-2 and -1

Thank you for this comment. We will modify this table as well and explain some details of the table in the captions (the procedure in Ch. 3. Methodology).

No.#1 See my remark on the Introduction

Thank you for this comment. As already noted, we shall modify the entire figure. And we shall modify the small inlet figure at the top right corner and use it in the Introduction as a schematic conceptual figure to present our overall approach.

In addition we shall separate the figures and thus resize it and make them better readable.

No.# 2 Legend is probably not readable

Thank you; you are correct. The figures shall be changed accordingly

No.# 3 It would be better to have a legend

Thank you; you are correct. The new version will have a legend

No.# 4 not readable

Thank you; you are correct. We shall change this.

No.# 5 I think this figure wants to show too much. I would split it.

Thank you; you are correct. The figures shall be split.

No.# 6 s

Thank you; we shall revise the caption accordingly.

No.# 7 There is no a and b in the figure indicated

Yes, you are correct; thank you. The references for a and b shall be indicated.

No.# 1 a and b is missing

Thank you for this comment. You are correct; a and b shall be included here as well.

No.# 2 What is UBK?

Thank you for your comment. We shall explain the abbreviation UBK in the chapter Methodology (and briefly in the captions here).

No.# 3 F Change this everywhere

Yes, thank you. As already noted, we shall change all the word 'formation', when using it as specific name, not only as a general term in to 'Formation' with capital F. (The existing literature is divided on this point.)

No.# 4 s

Thank you for this comment. However, we here show only one inlet photo (so, a plural 's' would be misleading).

No.# 5 o

Thank you for this comment. We shall modify accordingly.

Page: 30

No.# 1 Scale of map, north arrow is missing

Thank you. You are correct, the scale & north arrow shall be added.

No.# 2 I am unclear what this sub figure is showing

Thank you for the comment. You are correct. We shall elaborate on this in the figure captions: the inlet figure shows the hydraulic boundary conditions for the spring group Beitillu. We shall explain the captions (and in the text) that most hydraulic boundaries are no-flow boundaries that run along the line of lithostratigraphic changes from permeable to impermeable; only a very small portion of the hydraulic boundaries (and here the small part indicated in blue) represent flow boundaries. We here set it as a stream-flow boundary according to the prevalent local groundwater flow direction.