## General comments

In this study, the authors apply a methodology based on the landscape classification (geology, soil, land use and land cover) to achieve a regionalization of the recharge. This is done in the Wadi Natuf (occupied Palestinian west bank) watershed which is mostly poorly monitored regarding groundwater (wells) and spring discharge. This appears to be in fact an extension of a recently published work where recharge was estimated at different locations within the basin. The main findings are the identification of land surface features controlling the recharge, here geology, soil thickness, and LU/LC, the mapping of recharge coefficients and an overall recharge rate.

Recharge assessment and regionalization are crucial issues especially in arid to semi-arid domains where groundwater is a major source for water supply. In addition, recharge estimates are rare and difficult to obtain in arid to semi-arid domains which can be seen from the few available values in global synthesis papers. This is exactly the reason why I am generally in favor of studies like the ones presented here, as long as they meet the requirements of a publication in the concerned journal.

I feel uncomfortable with the "novelty" claimed by authors. The use of geological, soil, landscape descriptors for classification purpose to obtain recharge rates (values and distribution) has already been proposed and formalized in published guidelines and/or publications.The authors need to further argue this point and make it clear that such novelty maybe "restricted" to ungauged karstic aquifers.

The manuscript is generally well written, but some parts are unnecessarily long which hinders the fluidity of the reading making it difficult to really capture the ideas and concepts pivotal to the study. This is especially the case for the introduction which looks like more a review. The structuring in subsections in the introduction could be discarded, and the text largely shortened: six sentences l. 29-34 to arrive to the conclusion that the catchment scale is relevant for fluxes identification seems too much for instance. Subsections 1.1&1.3 and 1.2&1.4 could be merged and shortened to give a general context of recharge estimates using landscape characteristics and observations (discharge hydrographs,..).Then the specificity for karstic domains should be more precisely given followed by some information about previous studies and main outcomes in the WAB (section 1.5). Finally, the scope and goals (merging 1.6&1.7) of the present study clarifying the real novelty should be presented. In fact, this is the actual story, but a more concise form would be fine.

There is some confusion or even ambiguity associated with the term "ungauged" as used here. In my understanding, "ungauged basins" refer to watersheds where stream (or spring) discharge is poorly known or even not known at all. Here, the ambiguity is left because in karstic regions springs can be ungauged, the Wadi Natuf can be ungauged as well but the authors mention ""gauged though hundreds of Israeli deep wells" suggesting that gauged/ungauged refers to aquifer monitoring by wells. This needs an early clarification in the manuscript especially if this is claimed as part of the "novelty" of the proposed work.

I found the classification and the transposition into Recharge coefficients very confusing as described in the methodological section. There are some apparent (?) inconsistencies, five classes are proposed but six are used in Figure 5. All this need an extra effort of clarification (see comments 27-28).

**Specific comments**

1) Abstract: The first two or even tree sentences introduce some confusion about the real novelty of the work. Recharges had attracted attention and attempts to provide spatial distributions at local, continental scale or worldwide were made (some reference provided below among others). A distribution over USA is provided in the reference Scanlon et al. (2006) cited by the authors for instance. The same can be said for the reference Zomlot et al. (2018) who provide GW recharge spatial distribution in the Flanders region, Belgium. Unless authors are directly focusing on ungauged AND karstic basins the sentence "relatively little attention has been paid to its spatial distribution" seems somewhat exaggerated. This has to be convincingly stated and argued. In addition, it can be reasonably expected that in arid to semi-arid domains non perennial rivers (wadis) are hardly gauged and the ungauged state is an "internal characteristic".

Baalousha, H.M., Barth, N., Ramasomanana, F.H., Ahzi, S. (2018) Groundwater recharge estimation and its spatial distribution in arid regions using GIS: a case study from Qatar karst aquifer. *Model. Earth Syst. Environ.*4, 1319–1329 (2018).

Jaafarzadeh, M.S., Tahmasebipour, N., Haghizadeh, A., Pourghasemi, H.R., Rouhani, H. (2021) Groundwater recharge potential zonation using an ensemble of machine learning and bivariate statistical models. *Sci Rep*, 11, pp. 5587.

MacDonald, A.M., Lark, R.M., Taylor, R.G., Abiye, T., Fallas, H.C., Favreau, G., Goni, I.B., Kebede, S., Scanlon, B., Sorensen, J.P.R. Tijani, M., Upton, K.A., West, C. (2021) Mapping groundwater recharge in Africa from ground observationsand implications for water security. Environ. Res. Lett., 16, 034012.

Mohan, C., Western, A. W., Wei, Y., and Saft, M.: Predicting groundwater recharge for varying land cover and climate conditions – a global meta-study, Hydrol. Earth Syst. Sci., 22, 2689–2703, https://doi.org/10.5194/hess-22-2689-2018, 2018.

Richts, A., Struckmeier, W.,Zaepke, M. (2011): WHYMAP and the Groundwater Resources of the World 1:25,000,000. In: Jones J. (Eds.): Sustaining Groundwater Resources. International Year of Planet Earth; Springer. doi: 10.1007/978-90-481-3426-7_10

Tillman, F.D, Pool, D.R., Leake,S.A (2015) The Effect of Modeled Recharge Distribution onSimulated Groundwater Availability and Capture, *Groundwater*, 53, pp. 378–388.

2) p. 1, lines 25-26: it can be stated that an average (long-term?) recharge of between 233 and 272 mm $yr^{-1}$ was obtained.

3) p. 1, lines 28-30 : This assertion may be moderated in view of comment 1)

4) p. 2, line 5 "etc" can be removed" or cite the other drivers.

5) p. 6, line 6: in my moderate experience of karstic aquifer, wells are rarely available.

6) p.2, line 36: the term bedrock is usually restricted to crystalline rocks it is useless here. Besides recharge estimates using hydrological water balance (requires surface water information such as stream discharge) or Water Table Fluctuation method ( requires piezometric level information), Scanlon et al. (2006) do not recommend but report methods based on unsaturated zone observations or modeling.

7)p.3, line 7 "lithology" is repeated here, I suppose that "mineralogy" is more appropriate

8) p.3, line 9 Why "land use" is repeated, I was expecting 3 groups with different criteria

9) p.3, lines 6-11: fractures density is not a criterion in karstic domains?

10) p.3 line 20 : "calibrated model parameter": this is too vague what kind of model rainfall-runoff? recharge? other?

11) p 3, line 42 "In ungauged catchment, signatures" : In my understanding, "signatures" such as stream or spring hydrographs are not or poorly available in ungauged catchments (see also general comments)

12) p.4 lines 9-12: Is there a semi-permeable layer in between?

13) p.4 lines 19-20 : if "gauging" refers to wells network, the expression "aquifer wells or piezometer monitoring network" would be more suitable..

14) End of Section 1.5: reader arrives at the end of this section without knowing the main findings of previous studies, no values for the recharge (CMB for instance) are provided..at least orders of magnitude would be useful.

15) p. 4, lines 51-52: please recall the criteria for "a basin classification framework" : land-use, soil, ..?

16) p.5 line 6 :Messerschmid et al., 2020 presumably; repeated many times.

17) p.5 line 15 "different recharge classes were differentiated" according to what king of criterion?

18) p.5, line 34 : “impermeable chalk”. This is quite surprising since chalk formations are hardly seen as aquitards. There are no fractures? The use of “low permeability” sounds better for such kind of lithology.

19) p.5, line 36 : 64.4% of the surface area covered by aquifers, what about the remaining fraction Yatta formation? From Figure 2, it is not clear.

20) p.6, line 5 : provide the significance of LBK UBK as given in Table 1.

21) p.6, lines 21-22: Are the springs perennial, seasonal?

22) p.8, lines 44,45: geology, soil and LU/LC were indicated as highly correlated (p. 8, line 17). Is this information not redundant?

23) p. 9, line 10: “chemism” sounds strange, maybe “mineralogical composition”?

24) p. 9, line 12 : “karstic feature” fracturing? Density of fractures…? Please bring more precision.

25) p.10, Table 2 avoid using etc, just mention that it is a generic example and more classes can be used.

26) p. 10, lines 15: It is surprising to read that LU/LC and geology “was not quantifiable in the field”. Why? A geological map is available, and authors indicate some modifications from field work. Is there a LU/LC map available? How precisely this missing information was “qualitatively differentiated and correlated”, citing the previous study is not enough.

27) p.10, line 21: eight modelled RC values mentioned, six (7 with the zero value, the origin of the value at 49.4% is not given) different values found in Table 4, 5 in bold red in column “2. Soil” of Table 4. This is too confusing, the complete and precise RC values (obtained only for Jer, u-UBK, Heb, l-UBK, and l-Yat after Table 3) should be recalled here.

28) p.10, lines 19-24: It is completely unclear here how precisely “extrapolation” and the transition from Table 3 to Table 4 works: u-UBK receives a recharge class “I” for group 1 and “II” for group 2 in Table 3 but has the same RC in Table 4 for these groups; u-LBK receives the recharge class “II” for groups 1&2 in Table 3 and a different RC value in Table 4.

How precisely these “specific RC-values” were assigned? Is the reader supposed to understand that the different recharge classes (I,..,V) are given the available RC values also known for modelled formations, then the non modelled formations are given the RC corresponding to their class as identified above for each group? If so, it is not clearly explained (see above for apparent inconsistencies).

| Hydro-Fm | Rech. class | RC (group 2 Table 4) |
|---|---|---|
| Jer | I | **57.3%** |
| u-UBK | II | **54.1%** |
| Heb | III | **45.3%** |
| l-UBK | III | **44.7%** |
| l-Yat | IV | **41.8%** |
| Aquitard(Sen,u-Yat, Qat, Tam) | V | **0%** |

Playing with the Table above, I don't arrive to Table 4 from Table 3 in line with the assertion that the transfer is done by group. There is a different but not clearly explained correspondence between recharge classes (I,.., V) and RC values per group. Please clarify how precisely RC *vs* classes relations are built per group: the above table is for group 2, provide the same with explanations for the correspondences in groups 1 (I:54.1; II:45.3; III:44.7; IV: 41.8; V:0) and 3 (I:57.3; II:54.1; III:**49.4?**; IV: 41.8; V:0).

The above table is slightly inconsistent (for class III) with the color bar legend in Figure 5 which unexpectedly accounts for "a 6$^{th}$ extra class".

29) p.10, line 24, insert “(see Table 3)” after “formations”.

30) Section Results: Except the global recharge, this section brings little additional information in comparison to the methodological section. A regionalization is presented Figure 5 for group 2. What is done with the other groups? The resulting map for the three groups could be represented in a 3 panels figure with the corresponding color scales.

31) p12, line 6: "aquiferal" first time I read such formulation, "aquifer" is enough.

32)p. 13 lines 9-22: Is this supposed to be a discussion or an introductive state of art?

33) p.13, line 21: what is a “moderate climate” temperate?

34) p.13, line 24 : " This study went a step further" of what? It is unclear.

35) p 13 line 33 to p. 14 line 5: This is a too lengthy preamble for an equifinality problem that is not really addressed here or a correlation issue between descriptors.

36) p.14, line 5-8: Is really equifinality addressed here or the uncertainty on recharge distribution. Equifinality problem would suppose that several recharge maps could reproduce some observation of the average recharge for instance (which is likely!).

37) p.14 lines 26-28: I don't find any elements supporting this discussion in the manuscript.

38) End of section 5.1: arriving at this stage, no word about the limitations or caveats of the approach which can be expected in a discussion.

39) Section 5.2: Maybe the following can be of some use..

Average recharge coefficients of between 23 and 52% (average 35%) for karstified carbonates (Allocca et al., 2014; Arfib and Charlier, 2016; Baudement et al., 2017; Martos-Rosillo et al., 2015; Polemio, 2016; Zagana et al, 2007), and between 10 and 21% (average 16%) for detritic aquifer formations (Seraphin et al., 2016; Yagbasan, 2016; Zagana et al, 2007) were reported in the north Mediterranean area (Spain to Turkey).

Arfib B., Charlier J.B., 2016. Insights into saline intrusion and freshwater resources in coastal karstic aquifer using a lumped Rainfall-Discharge-Salinity model (the Port-Miou brackish spring, SE France). J. Hydrol. 540, 148-161.doi:10.1016/j.jhydrol.2016.06.010.

Baudement C, B. Arfib, N. Mazzilli, J. Jouves, T. Lamarque, Y. Guglielmi, 2017. Groundwater management of a highly dynamic karst by assessing baseflow and quickflow with a rainfall-discharge model (Dardennes springs, SE France), BSGF – Earth Sciences Bulletin 188, 40 https://doi.org/10.1051/bsgf/2017203.

Martos-Rosillo S., Gonzalez-Ramon A., Jimenez-Gavilan P., Andreo B., Duran J.J., Mancera E., 2015. Review on groundwater recharge in carbonate aquifers from SW Mediterranean (Betic Cordillera, S Spain), Environ Earth Sci 74, 7571–7581. https://doi.org/10.1007/s12665-015-4673-3

Polemio M., 2016. Monitoring and Management of Karstic Coastal Groundwater in a Changing Environment (Southern Italy): A Review of a Regional Experience. Water 8, 148, doi:10.3390/w8040148.

Séraphin P., Vallet-Coulomb C., Gonçalvès J., 2016. Partitioning groundwater recharge between rainfall infiltration and irrigation return flow using stable isotopes: The Crau aquifer. J. Hydrol. 542, 241–253.

Yagbasan, O., 2016. Impacts of climate change on groundwater recharge in Küçük Menderes River Basin in Western Turkey, Geodin. Acta 28, 209-222, Doi:10.1080/09853111.2015.1121802.

Zagana, E., Kuells, Ch., Udluft, P., Constantinou C., 2007. Methods of groundwater recharge estimation in eastern Mediterranean - A water balance model application in Greece, Cyprus and Jordan. Hydrol. Process. 21, 2405-2414, doi:10.1002/hyp.6392.

40)p.14, line 16 "geology" as it appears in the manuscript and not "lithology"