International Journal of Forest Sciences (2021). 1(3): 95-104

A Review **Open Access**

Effects of Forest and Rangeland on Interception, Evapotranspiration, Soil Moisture and Ground water, Infiltration-a review

Yamuna Paudel[1] and Ashish Paudel[2]

1. Student at Faculty of Forestry, Agriculture and Forestry University, Hetauda, Nepal
2. Student at Faculty of Agriculture, Agriculture and Forestry University, Nepal

***Corresponding author e-mail:** yamunapaudel29@gmail.com

SUMMARY

Land use types and practices significantly influence hydrological properties. The hydrological properties like interception, infiltration, soil moisture and evapotranspiration varies with vegetation cover, topography, climatic conditions and soil properties. These properties don't have exact value for all areas i.e. they can have different values under same vegetation cover. The purpose of the study was to understand the effects of forest and rangeland/grasslands on various hydrological properties like interception, evapotranspiration, infiltration, soil moisture and ground water recharge. Interception and evapotranspiration were higher from woody vegetation due to aerodynamics roughness of trees in promoting increased evaporation in wet condition that the rate of evapotranspiration losses from forests and grassland were 1400 ± 100 mm yr^{-1} and 950 ± 50 mm yr^{-1} respectively. Soil moisture was found higher in area with small bulk density and higher abundance of pore spaces that some studies found moisture under grassland twice that under forest and some found higher moisture on forest with good management practices than in grassland. Ground water was found increased when forests were converted to rangelands; groundwater recharge would increase by $7.8 \pm 12.6\%$. Well managed forest land with coarse medium texture soil has higher infiltration capacity than grassland and bare ground. Study found mean cumulative infiltration 33.47 cm in forest and 8.4 cm in grassland. Different vegetation structure and their management practices impacts soil, climate and water cycle differently. So, it is very important to understand which vegetation type can be used in particular area. This study will help to understand the hydrological influence of woody and herbaceous plants and helps in practicing better land use practice in water related disaster vulnerable areas.

Key words: Hydrological cycle, Interception, Infiltration, Ground water, Forest

Citation: Paudel, Y., A. Paudel. 2021. Effects of Forest and Rangeland on Interception, Evapotranspiration, Soil Moisture and Ground water, Infiltration-a review. International Journal of Forest Sciences. 1: 95-104.

INTRODUCTION

Many critical processes in the water cycle are regulated by forest and rangeland. The vegetation has a significant impact on interceptions, evaporation, precipitation absorption, and water transpiration into the atmosphere. It also has an impact on the surface and subsurface circulation of water via infiltration and percolation. These processes can have an impact on both the quantity and quality of water derived from forests and rangelands (Bonan, 2008). Changes in vegetation with succession and reforestation may also influence hydrology that grasses and deciduous plants tend to have a lower canopy resistance to transpiration than do conifers (Kelliher *et al.,* 1993; Bonan, 2008); thus, these plants have a higher transpiration rate than conifers under the same weather conditions. Vegetation, by covering the soil, aids in the processes of infiltration, percolation, and aquifer recharging. Changes in forest succession phases as they relate to forest structure may have an impact on soil properties and hydrological processes (Wischmeier and Smith, 1978).

The interplay between vegetation and water have long been studied all around the world (Bosch and Hewlett, 1982). The hydrological cycle and, as a result, water resources are influenced by vegetation. Over time, tree planting can result in significant eco-hydrological changes in soil water properties (Perkins et al., 2012). Furthermore, whether living or dead, plant roots have a role in channelling and directing water flow through the soil, implying the occurrence of a hydrological reaction to a rain event (Sardans and Penuelas, 2014). The fundamental concept of water balance changes indicates the balance of water input and outflow, with precipitation serving as intake and evapotranspiration, soil moisture, and stream flow serving as output. Forests, for example, provide more humid air to the atmosphere than vast, low-vegetation areas such as grassland meadows (Bringfelt et al., 1999), which may be due to the forest's greater net radiation input. Due to increased transpiration, grasslands have a higher evapotranspiration rate than forests under dry summer circumstances. Data shows, however, that higher rates of absorption evaporate may lead to increased yearly total evapotranspiration in forests (Robinson and Dupeyrat, 2005). Trees can require more water than most other forms of vegetation: forested catchments use substantially more water than grasslands (Bosch and Hewlett, 1982). However, as established by (Robinson and Dupeyrat, 2005), base-flow parameters in forest and grassland catchments are not necessarily distinct.

The dynamics of soil water content show a similar trend in the forest and grassland soil profiles. The noteworthy difference is that the soil dried out more in the woods than that in the grassland at levels below 20 cm. It is possible that this is because to trees drawing more water from deeper levels than grass species (Adane et al., 2018). The rate of evapotranspiration in untouched forest land is at about 1400 100 mm yr1 (Roberts et al., 2005) and closer to 950 50 mm yr1 in mildly seasonal grasslands (Scott et al., 2005; Grip et al., 2005). Bruijnzeel (2004) found low rainfall opportunities, insufficient groundwater replenishment during rainy season and strong decline in dry season flow of water in grazed grassland whereas he found mature tropical forest typically infiltrates 80%–95% of incident rainfall. Based on these estimates, replacing trees with grasslands would result in an increase in annual water production of 300 to 400 mm/yr (Bruijnzeel *et al.,* 2004). According to certain research (e.g., Poulenard et al., 2001; Yimer et al., 2008), the conversion of forests to grazing grounds reduces infiltration rates, with infiltration rates shown to be 88 percent lower in grazing lands than in forests. Reduced infiltration rates result in decreased groundwater and overall availability of water (Cardwell, 2017). The aim of the study was to find out the effects of woody and herbaceous plants on interception, evapotranspiration, soil moisture, ground water recharge and infiltration. The findings from the study will be suitable for policy makers and decision makers on watershed management activities and soil and land conservation. It will guide managers to select appropriate land use type to establish near watershed catchments to maintain proper water balance.

EFFECTS OF FOREST AND GRASSLANDS ON HYDROLOGICAL COMPONENTS

The hydrological cycle is the transport of water from the seas and land surface to air, then back to the seas via the land surface or underground (Bonn, 2008). The hydrologic cycle and its accompanying water budget provide a straightforward but powerful framework for examining how changes in plant cover impact water availability. Evaporation, precipitation, interception, infiltration, soil moisture, ground water recharge, and other natural processes are included (Bonn, 2008; Amataya et al., 2016). The water budget is simplified in Equation 1, which divides precipitation (the primary driver of the potential for plant removal to affect stream flow) into (1) evapotranspiration, (2) runoff, (3) groundwater, and (4) soil water:

$$P=ET+R+G+AS, \quad (1)$$

Where,
P = Precipitation
ET = Evapotranspiration
R = Runoff
G = Groundwater recharge
AS = Change in soil water storage

EVAPOTRANSPIRATION

vapotranspiration refers to the collective acts of actual evaporation just at surface of the ground, direct evaporation on vegetation, and transportation (Bierkens, 2015). It is of special relevance to watershed managers because it has a substantial influence on an area's water yield characteristics and is frequently modified by forest and range management methods (Amayata et al., 2016). Changes in vegetation with succession and reforestation may also influence evaporation. Vegetation with low canopy coverage like grasses, shrubs and deciduous plants tend to have a lower canopy resistance to transpiration than do conifers (Kelliher *et al.,* 1993; Bonan, 2008); thus, these plants have a higher transpiration rate than conifers under the same weather conditions. Evapotranspiration losses from forests were greater than those from grassland, according to the findings of a research on wooded and pastured watershed catchments. Variations in land use, as defined by different vegetation patterns, resulted in alterations in water balance, as seen by increased surface runoff and river discharge owing to evaporation shifts. Evaporation losses in the forest canopy environment were twice as high as in grassland due to the peculiar meteorological conditions, which remained damp for much of the year (Madani et al., 2018). As a result, with mean annual rainfall of "600, 800, 1300, 1500, and 1800 mm", a fully wooded eucalyptus catchment evaporates "40, 90, 215, 240, and 250" mm more per year than a grass-covered catchment (Holmes and Sinclair,1986). Gush (2006) simulated the impacts of afforestation on evapotranspiration for South Africa and found that when grassland was transformed into a forest plantation, evapotranspiration increased. In an Andes study, researchers discovered that Pinus ponderosa and Douglas fir forests transpired more water (approximately 1 mm•day1) than natural grassland (Bonnesoeur et al., 2019).

INTERCEPTION

Raindrops are intercepted by plants by releasing kinetic energy, which varies with plant height, leaf area, canopy cover, plant design, rainfall frequency, rainfall duration, volume of precipitation, kind of precipitation, and time of precipitation (Blackburn, 1975). Water is absorbed and dissipated before it reaches the soil surface during small thunderstorms, which can be considerable, especially in shrub, tall grass, mixed grass, and bunchgrass habitats. In comparison, part of the collected water goes down the stem or branch of the plant and into the soil (Goodrich et al., 2011). Tree interception is larger than grass interception on an annual basis; nevertheless, at maximum height, certain grasses have as much leaf area per unit area of ground as some trees. During the growth season, alfalfa can absorb the same amount of rain as a forest. The amount of water stored by grasses, bushes, and trees is proportional to their typical heights and ground cover (Goodrich et al., 2011). Interference losses from trees are often higher than those from other vegetation types, either to the aerodynamic roughness of trees in promoting increased evaporation in wet conditions or to their higher interception capabilities, particularly when wetted and dried repeatedly (Amataya et al., 2016). Per some studies, the juniper forest intercepts from 35 to 52 percent of the overall annual rainfall. Moreover, these studies didn't even address the heterogeneity of rainfall interception loss from plants with different canopies morphologies, resulting in significant uncertainty when extrapolating from tree level measurements to the stands or region scale. Tree canopy design metrics (e.g., open vs. closed vs. dense stands) may effect canopy storage space (S) and canopy target to funnel ratio (F), and thus net rainfall diversion into it via fall as well as stem flows (Owens et al., 2006). Watershed experiments in the south-central Great Plains indicated that transitioning rangeland from grassland to Cedar forest resulted in a considerable reduction in surface runoff owing to greater canopy interception by Cedar (Gilliam et al., 1987). The interception rate of bamboo litter was found to be 5.6 percent, whereas the interception rate of sal litter was found to be 9.1 percent (Amatya et al., 2016).

SOIL MOISTURE

Soil moisture content was twice as high in forest soil profiles as it was in cultivation and grazing regions. The increased moisture material in forest soil samples particularly in comparison to certain other land areas may be attributed to the soil's physical attribute, as illustrated by lower bulk cargo size and increased soil organic carbon content, resulting in a significant abundant supply of macro pores, greater infiltration and water content, and thus less water runoff (Yimer et al., 2008). Other research, like Shrestha and Kafle (2020), Tuffour et al. (2014), noticed greater soil moisture in pastures, which may be due to a drop in the pore space in the pastureland, causing a restriction in the transmission of water with the soil frequently to become too wet, resulting in higher amount of water available on the soil surface. Similarly, fine root length per unit amount of soil in grassland is 20 times greater than in forest (Jackson et al., 1997), and grasses have a better potential to reduce soil moisture per gramme in the Great Plains (Köchy and Wilson, 2000). These findings suggest that higher rates of water absorption by grasses may enhance the temporal variability of soil moisture content in grassland, since the coefficient of variation of moisture in grassland (62%) was twice that of forest (33 percent) (Peltzer, 2001). Similarly, research on higher altitude grasslands in the Andes revealed not only an outstanding ability for hydrological regulation and erosion mitigation, but also a water output up to 40% higher than tree plantings (Bonnesoeur et al., 2019).

GROUND WATER

Groundwater flow is typically the source of a stream's base flow, but it is unlikely to be an important pathway for storm flow due to the slow speed of groundwater transport (Blackburn, 1975). Plants may impact the flow and subsurface recharged parts of the water budget in a variety of direct and indirect ways. It may (1) change the character traits of soil infiltration via soil disturbance and organic material adding; (2) conserve soil moisture through shading and mulching; (3) draw off soil moisture through transpiration or interception; and (4) alter subsurface trajectories through root action that lead to the formation of contextual pores (Blackburn ,1975; Breshears et al., 1998). Woody vegetation collects soil water from deeper depths (assuming deep water exists) than herbaceous plants because it is more firmly entrenched. The term "groundwater recharge" refers to soil water that runs beyond the root zone and finally reaches an underlying water body (Scalcon, 1994). As forest area is converted to managed grasslands, groundwater recharge rises. The vegetation roots system, canopy interception capacity, and transpiration rates impact the influence of land use types on groundwater recharge (Taniguchi,1997), who discovered that deep-rooted native vegetation types had lower groundwater recharge rates. Furthermore, higher interception in forest systems limits water availability for groundwater recharge. Grassland interception losses, on the other hand, were found to be lower (Williamson et al., 1987), contributing to increased groundwater recharge rates. Groundwater recharge would increase by 7.8 12.6 percent if forests were cleared for rangelands, whereas conversion to grassland resulted in increases of 3.4 2.5 and 4.4 3.3 percent, respectively (Owuor et al., 2016).

INFILTRATION

Infiltration is the entrance of water into the surface of the ground, which serves as the sole source of water for vegetation development and contributes to the supply of groundwater to wells, springs, and streams (Blackburn, 1975). Soil structure, aggregate stability, particle sizes, land use type, vegetation (particularly vegetation and trash covers and type, and organic soil material), and topographic and climatic conditions all impact infiltration capacity, a major soil hydrological characteristic (Tromble et al., 1974; Wood and Blackburn,1981). Pasture use change from wild or semi-natural flora to grazing land has a substantial influence on permeability, aeration, penetration, flood control, water delivery qualities, and runoff (Cameron et al., 1981). Study on land use change impact on infiltration by Shrestha and Kafle (2020) found mean cumulative infiltration the 33.47 cm in forest and 8.4 cm in grassland which is similar to findings of (Yimer *et al.,* 2008) who found higher rate of infiltration under forest vegetation than under pasture land. Likewise, study on páramo ecosystem, the saturated infiltration rate of a pine plantation was three times higher than the rate of an ungrazed grassland (Quichimbo *et al.,* 2012). Afforestation on grazed grassland by woody plants strongly increased the saturated infiltration rate by 8 times after 14–20 years and led to a partial recovery of the soil infiltration capacity of grassland. But the saturated infiltration rate in grassland was three times lower than the rate in native forests (Bonnesoeur *et al.,* 2019).

Table 1: Net infiltration rates for different soils and land uses.

Soil category	**Bare soil**	**Pasture**	**Forest**
Coarse medium texture soil	0.3	1	3
Medium texture soil	0.1	0.5	0.6
Medium and fine texture	0.05	0.2	0.25

(Source: Amatya *et al.,* 2016)

SOME CASE STUDIES ON EFFECT OF FOREST AND RANGELAND ON HYDROLOGICAL COMPONENTS

The research conducted on forest and grassland found that forest used more water than the grassland; of 620 mm average annual precipitation, losses were higher through interception (29% under F, 16% for G) and groundwater (GW) recharge was enhanced under grassland at 37% (~225 mm) of precipitation compared with 12% (~73 mm) for the forest .Consequently, the average groundwater recharge under the forest was roughly a third of that under grassland (73 mm compared with 225 mm), primarily due to the trade□off with an interception and higher transpiration (Douinot *et al.,* 2019).

Table 2: Ground water and interception on forest and grassland

Land category	**Ground water recharge**	**Interception**
Forest	73 ± 67 mm , 12 ± 8.3 %	163 ± 31 mm , 29 ± 4.0 %
Grassland	225 ± 105 mm , 36 ± 10.4 %	104 ± 7 mm , 16 ± 2.7 %

Source :(Douinot *et al.,* 2019)

Conversely, a study conducted on the Nebraska Hills revealed that change from grasslands to dense pine forests resulted in vegetation-induced variations in soil hydraulic characteristics, higher rooting depth, and a greater leaf area index, all of which seriously affected the water budget. Field use alteration consequences, calculated as a percentage of gross precipitation, include a 7% increase in absorption due to the increase in leaf area, a nearly 10percentage spike in real evaporation and transpiration, and a nearly 17percentage - point loss in groundwater overall. Simulated average yearly recharging rates in the grassland plot reduced from 9.65 cm yr1 to 0.07 cm yr1 in the pine experiment (Adane et al., 2018). Study on forest and grassland coverage watershed (Madani et al., 2018) found land use with different vegetation resulted in different effects on hydrological components of water cycle. The main explanation suggested by the data presented on table 3 was that interception, evaporation, transpiration accounted for the major difference in the water balance between the forested and grassland watersheds. The differences in interception, evaporation accounted for the most important differences between forest and grassland. Soil evaporation from forest was found higher than that of grassland whereas total evapotranspiration was higher from grassland. And runoff from was found higher under forest.

Table 3: Water balance table for grassland and forest watersheds

Water balance	Grassland	Forest
Soil evaporation (mm)	112.48	132.15
Transpiration (mm)	251.62	208.42
Interception (mm)	265.33	193.25
Total evapotranspiration (mm)	629.53	533.72
Runoff (mm)	2,085	2,185

Source: (Madani *et al.,* 2018)

CONCLUSION

The land cover change i.e. forest cover and grass cover, has a different effect on the hydrological process. Well-managed forest or less distributed grassland both can be important on influencing the hydrological cycle. However, it is pretty challenging to determine precisely which type of cover can have more effect in hydrology. These hydrological processes are influenced by various features like soil properties, vegetation types, topography, microclimatic conditions, etc. and different practices like forest fire, grazing, forest harvesting, and etc. influence vegetation's role on hydrological processes. Some studies mention woody vegetation has more role compared to herbaceous grass in the interception due to their more aerial exposure. About 35 to 52% of total rainfall interception loss occurs from Juniper forest. Likewise, evapotranspiration from forest were twice as significant as in grassland. Soil moisture is controlled by bulk density, porosity and it depends on the compactness of land too. Soil moisture content in grassland was twice that under forest. Woody vegetation moves too deep, so this vegetation plays more role in groundwater than herbaceous. And infiltration is influenced by both soil textural as well as land cover change. Coarse medium texture soil under forest cover has more infiltration capacity than other. However, the hydrological properties are not constant in all places it can be higher either under woody vegetation or under herbaceous. It totally differs according to topography, soil, time, climate, soil depth, slope, etc.

REFERENCES

Adane, Z. A., Nasta, P., Zlotnik, V., Wedin, D. 2018. Impact of grassland conversion to forest on groundwater recharge in the Nebraska Sand Hills. Journal of hydrology: Regional studies, 15:171-183.

Amatya, S., Shrestha, K., Cedamon, E. 2016.Nepal Forestry Handbook. Nepal Foresters Association. Australian Centre for International Agriculture Research Australia.

Bierkens, M. F. 2015. Global hydrology 2015: State, trends, and directions. Water Resources Research, 51(7): 4923-4947.

Blackburn, W. H. 1975. Factors influencing infiltration and sediment production of semiarid rangelands in Nevada. Water Resources Research, 11(6): 929-937.

Bonan, G. B. 2008. Forests and climate change: forcing, feedbacks, and the climate benefits of forests. Science, 320 (5882):1444-1449.

Bonnesoeur, V., Locatelli, B., Guariguata, M. R., Ochoa-Tocachi, B. F., Vanacker, V., Mao, Z.... Mathez-Stiefel, S. L. 2019. Impacts of forests and forestation on hydrological services in the Andes: A systematic review. Forest Ecology and Management, 433: 569-584.

Bosch, J. M., Hewlett, J. D. 1982. A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. Journal of hydrology, 55(1-4): 3-23.

Breshears, D. D., Nyhan, J. W., Heil, C. E., Wilcox, B. P. 1998. Effects of woody plants on microclimate in a semiarid woodland: soil temperature and evaporation in canopy and intercanopy patches. International Journal of Plant Sciences, 159(6):1010-1017.

Bringfelt, B., Heikinheimo, M., Gustafsson, N., Perov, V., Lindroth, A. 1999. A new land-surface treatment for HIRLAM—Comparisons with NOPEX measurements. Agricultural and forest meteorology, 98:239-256.

Bruijnzeel, L. A. 2004. Hydrological functions of tropical forests: not seeing the soil for the trees? Agriculture, ecosystems & environment, 104(1):185-228.

Cameron, D. R., Shaykewich, C., De Jong, E., Chanasyk, D., Green, M., Reed, D. W. L. 1981. Physical aspects of soil degradation. In Proceeding of 18th Annual Alberta Soil Science Workshop, 186-255.

Cardwell, A. 2017. The effect of land use on infiltration in Taita hills, Kenya.

Douinot, A., Tetzlaff, D., Maneta, M., Kuppel, S., Schulte□Bisping, H., Soulsby, C. 2019. Ecohydrological modelling with EcH2O□iso to quantify forest and grassland effects on water partitioning and flux ages. Hydrological Processes, 33(16):2174-2191.

Gilliam, F. S., Seastedt, T. R., Knapp, A. K. 1987. Canopy rainfall interception and throughfall in burned and unburned tallgrass prairie. The Southwestern Naturalist, 267-271.

Goodrich, D. C., Guertin, D. P., Burns, I. S., Nearing, M. A., Stone, J. J., Wei, H., ...,Jolley, L. 2011. AGWA: the automated geospatial watershed assessment tool to inform rangeland management. Rangelands, 33(4) :41-47.

Gush, M. B. 2006. Modelling streamflow reductions resulting from commercial afforestation in South Africa: from research to application. In Proceedings of the International Conference on Forest and Water.

Holmes, J. W., Sinclair, J. A. 1986. Water yield from some afforested catchments in Victoria. In Hydrology and Water Resources Symposium 1986: River Basin Management; Preprints of Papers (p. 214). Institution of Engineers, Australia.

Jackson, R.B., Mooney, H.A. Schulze, E.□D. 1997. A global budget for fine root biomass, surface area, and nutrient contents. Proceedings of the National Academy of Sciences USA, 94:7362-7366.

Kelliher, F. M., Leuning, R., Schulze, E. D. 1993. Evaporation and canopy characteristics of coniferous forests and grasslands. Oecologia, 95(2):153-163.

Köchy, M., Wilson, S. D .2000. Competitive effects of shrubs and grasses in prairie. Oikos, 91(2), 385-395.

Madani, E. M., Jansson, P. E., Babelon, I. 2018. Differences in water balance between grassland and forest watersheds using long-term data, derived using the CoupModel. Hydrology Research, 49(1):72-89.

Owens, M. K., Lyons, R. K., Alejandro, C. L. 2006. Rainfall partitioning within semiarid juniper communities: effects of event size and canopy cover. Hydrological Processes: An International Journal, 20(15):3179-3189.

Owuor, S. O., Butterbach-Bahl, K., Guzha, A. C., Rufino, M. C., Pelster, D. E., Díaz-Pinés, E., Breuer, L. 2016. Groundwater recharge rates and surface runoff response to land use and land cover changes in semi-arid environments. Ecological Processes, *5*(1):1-21.

Peltzer, D. A. 2001. Plant responses to competition and soil origin across a prairie–forest boundary. Journal of Ecology, 89(2):176-185.

Perkins, K. S., Nimmo, J. R., Medeiros, A. C. 2012. Effects of native forest restoration on soil hydraulic properties, Auwahi, Maui, Hawaiian Islands. Geophysical Research Letters, 39(5).

Poulenard, J., Podwojewski, P.,Janeau, J. L., Collinet, J. 2001. Runoff and soil erosion under rainfall simulation of Andisols from the Ecuadorian Páramo: effect of tillage and burning. Catena, 45(3):185-207.

Quichimbo, P., Tenorio, G., Borja, P., Cárdenas, I., Crespo, P., Célleri, R. 2012. Efectossobrelaspropiedadesfísicas y químicas de los suelospor el cambio de la cobertura vegetal y uso del suelo: páramo de Quimsacocha al sur del Ecuador. SuelosEcuatoriales, 42(2):138-153.

Robinson, M., Dupeyrat, A. 2005. Effects of commercial timber harvesting on streamflow regimes in the Plynlimon catchments, mid□Wales. Hydrological Processes: An International Journal, 19(6): 1213-1226.

Sardans, J., Peñuelas, J. 2014. Hydraulic redistribution by plants and nutrient stoichiometry: Shifts under global change. Ecohydrology, 7(1):1-20.

Scanlon, B.R. 1994. Water and heat fluxes in Van Auken, O.W. 2000. Shrub invasions of Alamos-Jemez Mountains Region. desert soils 1. field studies. Water Resour. North American semiarid grasslands. Ann. Wright, H.A., F.M. Churchill, and W.C. Res. 30:709-719.

Shrestha, S., Kafle, G. 2020. Variation of selected physicochemical and hydrological properties of soils in different tropical land use systems of Nepal. Applied and environmental soil science.

Taniguchi, M. 1997.Subsurface water responses to land cover/use changes: an overview. Subsurface Hydrological responses to land cover and land use changes, 1-20.

Tromble, J. M., Renard, K. G.,Thatcher, A. P. 1974. Infiltration for three rangeland soil-vegetation complexes. Rangeland Ecology & Management/Journal of Range Management Archives, 27(4):318-321.

Tuffour, H. O., Bonsu, M., Khalid, A. A. 2014. Assessment of soil degradation due to compaction resulting from cattle grazing using infiltration parameters. International Journal of Scientific Research in Environmental Sciences, 2(4):139.

Williamson, D. R., Stokes, R. A., Ruprecht, J. K. 1987. Response of input and output of water and chloride to clearing for agriculture. Journal of Hydrology, 94(1-2):1-28.

Wischmeier, W. H., Smith, D. D. 1978. Predicting rainfall erosion losses: a guide to conservation planning (No. 537). Department of Agriculture, Science and Education Administration.

Wood, M. K., Blackburn, W. H. 1981. Grazing systems: their influence on infiltration rates in the rolling plains of Texas. Rangeland Ecology & Management/Journal of Range Management Archives, 34(4):331-335.

Yimer, F., Messing, I., Ledin, S., ABdelkadir, A. 2008. Effects of different land use types on infiltration capacity in a catchment in the highlands of Ethiopia. Soil use and management, 24(4):344-349.