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Evaluation of executable best management practices in Haean highland agricultural catchment of South Korea using SWAT

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ABSTRACT

This study is to evaluate the reduction of high level nonpoint source (NPS) pollution discharges in Haean highland agricultural catchment (62.8 km^2) by applying best management practices (BMPs) of vegetation filter strip installation (VFS), fertilizer control (FC), and rice straw mulching (RSM) in uplands above 600 m of elevation using SWAT (Soil and Water Assessment Tool). From the modeling results, the VFS BMP showed the best performance to reduce sediment (SS) of 16.0% for 1 m strip width up to 34.8% for 5 m strip width and total phosphorus (T-P) discharge loads of 5.1% to 21.3% from highland crop areas. The FC BMP showed the discharge loads reduction of 4.9% for 10% fertilizer reduction up to 16.4% for 30% fertilizer reduction. The RSM BMP results showed the sediment reduction of 3.0% for 6.0% runoff reduction up to 14.1% for 17.0% runoff reduction and T-P reduction of 1.3% for 6.0% runoff reduction up to 6.8% for 17.0% runoff reduction by showing negative effect of total nitrogen (T-N) up to −3.7% for 12.0% runoff reduction. However, because of the difficulties to install vegetation filter strip by farmers unwillingness in South Korea, the BMPs combination of fertilizer reduction and rice straw mulching (FC + RSM) was suggested as an executable BMP to obtain positive removal efficiency for all nutrient discharge loads. The FC + RSM BMP showed sediment, T-P, and T-N reductions up to 9.7%, 8.1%, and 9.2% respectively.

1. Introduction

The traditional small-scale upland agriculture before the middle of 1980s in South Korea has employed eco-friendly cultivation methods with their self-production animal manure circulation to farmlands that give low impact to watershed environment and are harmonious to natural ecosystem. However, the upland reclamation areas have been increased with abuse for chemical fertilizers to increase crop productivity. Since after, they have caused the adverse effects on water quality problems to stream and groundwater.

Now in particular, the highland agriculture densely distributed at the northeastern mountain hill areas of South Korea has serious problem to stream and lake water quality maintenance by their special cultivation practices. The highland agricultural areas need allochthonous soil addition for artificial top soil layer formation every year by the high soil loss by the intensive rainfalls during summer Monsoon season of June to September (Ministry of Environment, 2004). The representative highland crops are soybeans, radishes, cabbages, potatoes, and carrots with a growing duration of 90160 days, 2540 days, 120 days, 120 days, and 100–120 days each and begin to seed from March and harvest from July to October.

In the last couple of decades, the expansion of highland agriculture, extremely high applications of synthetic nitrogen (N) fertilizers in dryland farm fields, the expanded planting of crops has led to high nitrogen release except soybean from mountainous landscapes in South Korea (Kettering et al., 2012). The high N inputs to farm fields permit increases in summer vegetable production from highland areas for the urban peoples food supply, but with the increased landscape-level exports that decrease freshwater quality (sediment and nutrients) in downstream reservoirs.

As found in global trends, the phosphorus (P) is also accumulating through fertilization in highland agricultural areas. The rains together with prevailing dryland farming practices on steep slopes lead to large exports of sediments and total P to the reservoirs (Park et al., 2010). In fact, several small catchments from highland cultivation areas export the world highest recorded levels for total N and P due to the excessive use of fertilizers and soil loss (Kim et al., 2001). The high background levels of N provide for high potential algal growth, algal blooms and eutrophication in response to monsoon-rain-based pulses of P.

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To reduce nonpoint source (NPS) pollution occurring in the agricultural basin in highlands effectively, best management practices (BMPs) can be used (Gitau et al., 2004; Zhen et al., 2004; Maharjan et al., 2016). The BMPs can be divided into non-structural and structural methods. Non-structural methods refer to agricultural management methods using fertilizer amounts, rice straw mulching, no tillage, etc. while structural methods refer to the installation of pollution-reduction facilities, such as vegetative filter strips, grass swales, and sediment basins. Hamada and Reineking (2016) reported that the 5 m vegetated field margins next to radish fields can mitigate negative impacts of soil erosion off-site by trapping eroded material under managed and natural slopes at the same watershed of this study. For the various BMPs, it is necessary to derive its applicability to agricultural basins in highlands as well as to quantify the efficiency of NPS pollution reduction when applying the BMPs. Since their effectiveness cannot be tested in all watershed situations, watershed managers rely on models to provide an estimate of their impact on improving water quality at the watershed scale (Arabi et al., 2007).

The SWAT (Soil and Water Assessment Tool) (Arnold et al., 1998) has a large number of studies on the watershed scale BMPs application to control NPS pollution discharges. Recently, Parajuli et al. (2008) quantified the effects of using vegetative filter strips in the 950 km^2 Wakarusa watershed in northeast Kansas, resulted in 63% decrease in sediment. Lee et al. (2010) evaluated the reduction in NPS pollution discharges by applying BMPs (vegetative filter strips, riparian buffer system and fertilizing control) for a 1.21 km^2 agricultural watershed, resulted in 16–25% reduction in sediment, 5–37% reduction in T-N, and 6–41% reduction in T-P respectively. Liu et al. (2013) evaluated NPS pollution of BMPs (conservation tillage, contour farming) in the 3099 km^2 Xiangxi river watershed that have the reduction efficiency of T-N by 8–9%, and T-P by 5–7%, respectively. Many studies have suggested the effectiveness for the reduction of NPS pollution discharges using BMPs (Rao et al., 2009; Zhang and Zhang 2011; Dechmi and Skhiri 2013; Strauch et al., 2013; Park et al., 2014). Maharjan et al. (2016) evaluated the BMPs of split fertilizer application (SF), cover crop cultivation (CC), and the combination (SFCC) at the watershed of this study using SWAT. They found that the SF scenario reduced nitrate pollution while sediment compared to single fertilizer application. The application of the CC scenario reduces both sediment and nitrate load. The SFCC showed the highest positive effect on reducing sediment and nitrate.

In this study, the three government recommended BMPs of vegetation filter strip (VFS) at each field margin, fertilizer control (FC) by amount and rice straw mulching (RSM) along the furrow were applied in a 62.8 km^2 highland agricultural watershed using SWAT and evaluated the level of NPS reduction effects of suspended solid (SS), T-N, and T-P at the watershed outlet. The SWAT hydrology was referenced from the study of Shope et al. (2014). During the SWAT evaluation, the field information of crop cultivation calendars, soil addition practices and fertilizer applications provided by farmers were used as modeling data and parameterized. We especially adopted soil bulk density parameter to consider the soil addition condition and the SCS-CN (Soil Conservation Service-Curve Number) to evaluate the surface reduction by RSM during SWAT modeling and BMP evaluation. Fig. 1 shows the schematic flow chart of this study.

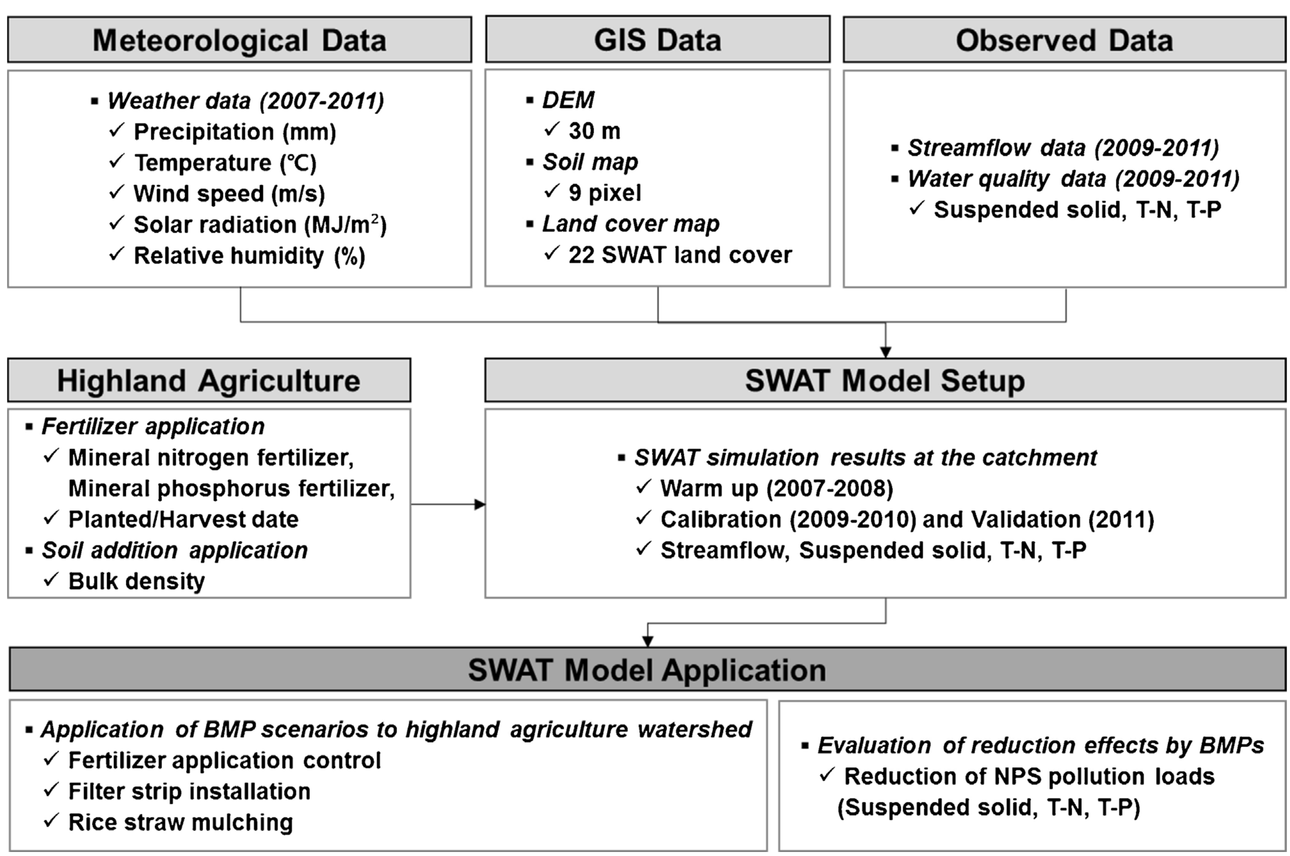

Fig. 1. Flow chart of this study.

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