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Impact of Landuses on Air and Water Quality- A Review

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Abstract

Landuse alteration is one of the primary causes of global environmental change. Changes in the landuse usually occurred regionally and globally over last few decades and will carry on in the future as well. These activities are highly influenced by anthropogenic activities and have more serious consequences on the quality of water and air. In the present study relationship between land use impact on water and air quality have been reviewed.

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Introduction

Land use and land cover are the two dissimilar words where landuse refers to occurrence of anthropogenic actions on land (i.e., agriculture, urban, peri-urban, pasture etc.), whereas total vegetative cover on the land surface is regarded as land cover (i.e., forest or desert). It is widely known that changes in land use and land cover at local and global scales is one of the important driving factors of global climate change.[1,2] Water and air are the two most important components that intensely influence all types of life on earth and, indiscriminate use of chemical fertilizers and pesticides to raise crop productivity in agriculture sectors causing contamination of air and water bodies lead to deterioration of air and water quality. Land use and land cover are important elements in relation to water and air quality. There are different types of land use and land cover, which affect the quality of water and air. Land use impacts water and air quality through non-point sources, which are major sources and contributor of water and air pollution. Changes in land use affected land cover, while changing land cover similarly affects the land use. While, along with progress in plant life cycles, the land cover varied seasonally in natural and agricultural lands. Land cover is very limited in urban areas because of concrete, asphalt and buildings cover on the land's surface.

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Sometimes, natural processes occurred in the environment like various biological, hydrological, meteorological, sedimentation etc. may caused deposition of undesirable compounds, which imbalance the chemistry of water (surface and ground) and air. According to many researchers land use and land cover changes mostly occurred from human development action where land offered unnecessary nutrients and sediments to surface waters.[3,4,5,6] In actual fact research on land use and land cover change is multidisciplinary and draw attention of researchers from various fields, like GIS, geography, economics, and demography. Presently, Land-Use and Land-Cover Change (LULCC) is one of the most important caused of global environment change. It is very important to consider both land use and land cover simultaneously in the study of the impacts of land use on the water quality.[7]

The release of reactive N species to water and air affected various life forms on the Earth in a variety of ways[8] such as groundwater pollution due to leaching of (nitrates) NO_3, eutrophication of water bodies, terrestrial eutrophication, which diminished diversity of species, soil acidification, destruction of stratospheric ozone due to N_2O and global warming.[9,10] The vegetation destruction and the land use transformation into urban areas identified as to enhance the run off, which also facilitates the transfer of undesirable material from land to aquatic bodies.[11] Generally, in monsoon season, most of the variables worsened due to increased runoff which carried impurities into the water bodies. Colloidal matter like silt, clay, organic and inorganic matter causes water turbidity and exacerbated the condition of water quality. Therefore, this review article reviewed the work done by different researchers on landuse effects on water and air quality.

Effects on Water Quality

In 2005, Vörösmarty described fresh water as a valuable natural resource whose quantity and quality is very important for development of sustainable life.[12] Recently, the quality of water becomes an important issue as human and ecological health directly affected by deteriorated water quality. The use of groundwater and its influence on current water chemistry needs to be accurately described to quantify the temporally varying impacts of land use on water quality. Groundwater recharge is also affected by LULCC in semi-arid or arid areas. In arid and semiarid regions groundwater recharge variations linked with LULCC having negative impacts on groundwater quality as thick unsaturated zones contained salt reservoir that accumulated in surplus of thousands of years.[13,14,15] Expansion of built-up areas posed direct and indirect threats to the veracity of water bodies.[16] Different water pollution problems are associated with different land use pattern and changes. For instance, Tong and Chen in 2002 Ohio State, USA examined the land use interaction with water quality and found that TP (Total Phosphorus) was considerably positively linked to agricultural, commercial and residential areas but non-significant with forest whereas, BOD had a positive relationship with residential and commercial lands, negative connections with forest, but non-significant association with agriculture landuse[17] and the transport of surplus nutrients and sediments through various processes like leaching, runoff, volatilization etc. rapidly reach to the water bodies due to lack of vegetative cover.[18] Another example is of the northern stretch of land north of Kansas State University (the blue highlighted area), the Marlatt Watershed and this area is subdivided between agricultural land use and urban land use. They took water quality samples by a HACH® Test Kit and using the citizen science method and recorded data into the ArcGIS mapping system.[19] In Bagmati River, Nepal a positive correlation found between population density and water quality deterioration.[20]

Deforestation and degrading activities such as river sand mining waste disposal and cultivation on river bank affected the water quality of Bagmati River.[21,22] In Kashmir, water quality of Wular lake deteriorated due to different land use pattern (agriculture, urbanized and wasteland) impact on surface water.[23] Various physico-chemical variables were analysed by[24], ERDAS IMAGINE 9.0 and ArcGIS 9.3 for creating land use and land cover maps and for various LULC categories (IRS) P6 using LISS III sensor with a spatial resolution of 23.5 m. In addition, man-made fertilizers, which are applied in agriculture and built-up areas, these transported off to fields or through groundwater by various known processes like leaching, runoff

and then transferred to surface water bodies via groundwater transport.[25,26] In 2009, according to Pitt *et., al* the N fertilizers application lead to denitrification, which in turn lead to deposition in atmospheric environment of nitrogen and surface water bodies also. Another example is of Mississippi River, where estimation of 89% of nitrate-nitrogen concentration has came from agriculture activities.[27] A relationship is frequently originate when it was examined that the changes in the different land areas for human settlements or for their requirements and the effects of these modified land areas on water quality within a watershed. Among different land uses agriculture area shattered maximum fertilizers in the lake, resulting in the depletion of dissolved oxygen (DO) content by growth of micro-organisms in the water body and imbalance the water chemistry.[28] A study was conducted in Tamilnadu, Ooty town of Nilgiris district, to assess the influence of urbanization especially changing land use patterns on water quality and quantity.[29] They checked the groundwater quality parameters and spatial maps were prepared within geographical information system (GIS) using ArcGIS software. By using landuse maps they indicated that the forest area was reducing and was replaced by industries and houses. Forest land showed negative correlation with all parameters except pH, which thereby showed that the concentration of other parameters decreased with increase in the forest area. Residential area has positive correlation with all parameters except pH, this indicated that increase in residential area will increase the concentration of the water quality parameters beyond the permissible limit. Increase in urbanization decreases infiltration. There have some reports which concluded that water table is deteriorating at the rate of 1–2 m/year in many parts of the country.[30]

The quantity and quality of groundwater were changing due to human activity. Since the era of industrialization and rapid population growth, land use change phenomena have strongly accelerated in many regions, which directly impacting the hydrology of the catchment area also concluded in their results that the water quality has been deteriorating by urban development and mainly affects the surface water.[31,32] In Jakarta, Ciliwung is the biggest river, which has found to be degraded due to land use patterns and changes. The status of water quality under different land use within the Ciliwung watershed has been analyzed on the basis of remote sensing data and water quality monitoring data in the years 2010 and 2014. Their results exhibited more considerable variations in water quality variables among the forest and urban-dominated areas. In Jakarta, Depok, Bogor and neighbouring areas the high density of population resulted in land use and land cover changes, which indirectly affected water quality in Ciliwung River.[33] Landuse changes have an effect on water quality, proved by few researchers for example, by introduction of nitrogen species and other biologically active compounds.[34,35] In 2006, Schlesinger *et., al* determined high nitrate concentrations in ground water of agriculture areas which was expected to be of anthropogenic origin. Changes in landuse affected the quality of water by major modifications of residue budgets.[36,37]

Few studies has found large effects of dryland agriculture on water bodies such as growing recharge and flushing accumulate salts to rivers.[38,39] It has been found that agriculture fields have been over charged with N and P during cropping seasons which cause unproductive nutrient use and groundwater pollution and can contaminate nearby water body. They used a model known as zone monitoring model which is considered to be an appropriate monitoring scheme to analyze the risks for groundwater which comes from agriculture lands. According to zone monitoring model, different methods like suction lance, direct-push method used for groundwater sampling, soil samples which are beneath the groundwater table are used to monitor nitrate concentrations from the agriculture fields to the soil region and on to the groundwater. The water quality status of river called Dongjiang in South Eastern; Chinawas examined in relation to land use (e.g. urban, forest, and agriculture) in dry and rainy seasons.[40] In 2015, Ding *et., al* found stronger impacts of forest and urban land use on water quality in dry season comparative to rainy season and the agriculture land use created pathetic impacts on water quality in contrast with urbanized land area.[41] In Chaohu lake of China the water quality was very fine due to good ecological environment in the early period. But due to change in land use system, the downstream ecosystems and hydrological conditions have been changed as the discharge

from the local manufacturing units, cultivated land, and daily life.[42] By using statistical analysis, Huang *et., al* have studied stream water quality in Chaohu lake basin, China. Their statistical model showed that between the years 2000 and 2008, built up land in the basin was positively correlated with most of the water quality variables whereas, forest, grassland and water bodies were negatively correlated with most of the variables.[43] Locally, the increasing urbanized areas impacted quality of aquatic bodies [44,45], groundwater recharge [46,47] and storm discharge.[48] Hatt *et., al* found similar results like extension of urban land has a direct relationship with the water body and it increased Total Dissolved Solids in river water.[49] Muñoz *et., al* found that between the years 1998 and 2006, 53% of forest land converted to pasture and cropping land in lake Rupanco basin, Chile and increased nitrogen in the lake water from 33 kg TN/km^2/y to 621 kg TN/km^2/y.[50] Dabrowski *et., al* also assessed the agricultural activity impact on water quality.[51] Watersheds in urbanized areas had higher nitrogen yields while forested watersheds within the forest land had considerable lower yields of nitrogen and nitrogen compounds.[52]

In 2011, Chidya *et., al* investigated the water quality status of Likangala River, which shown contamination at most of the sampling sites with phosphates, *E. Coli*. The deprived agricultural practices such as runoff from fertilisers, cultivation on bank of river and urban pollution where different settlements were close up to the river and sewage discharged into the river water and deteriorates its quality. Water quality samples were collected in both dry and wet seasons to assess river health, as there are seasonal variations caused by rainfall and increased runoff that can affect water quality.[53] In Southern Malawi, water quality of Likangala River that passes through a Zomba city was analysed by Pullanikkatil *et., al* in 2015 and found that in both dry and wet seasons the water quality has been found to be normal and sometimes bad at the sampled sites and not suitable for human consumption without treatment.[54] A study was conducted in China on Guishui river, for the estimating the recharge availability of land use in relation to hydrological process and found reduction in groundwater recharge in order of cropland, grassland, urban land and forest respectively.[55] In Ziarat watershed, Yones *et., al* found water quality status in relation to four land use: urban development pasture, forest and cultivated.[56] According to an U.S. Geo¬logical Survey conducted in 1999, they found an elevation in nutrient surplus in nearby water bodies within agricultural areas due to inputs of nutrients from fertilizers and manure.[57] Urbanized areas consisted of various land uses like office, residential, industrial and other built area when it was compared with other landuse, then it has been found that urban land produces more wastewater.[58] The urbanized areas expanded more resistant areas, which led to flow of storm at faster rate and have better volume of runoff. Impermeable pollutants (e.g., non-point source and point source pollutants) runoff into river that increased nutrient level and other unsuitable compounds in aquatic bodies.[59] According to Sun *et., al* in suburban areas the infrastructure also contributed to increase in nitrogen level, if there is a shortage in treatment of wastewater treatment.[60]

A study was conducted in the Manyame river upstream catchment in Zimbabwe and found that during the years 1995 and 2012, grassland, bare and forest land area decreased by 22.6%, 31.7% and 24% respectively whereas, agricultural actions and urbanization increased by 24.4% and 41.6% respectively.[61] This landuse change increased total phosphorus (TP) load from 130 kg/day to 376 kg/day and total nitrogen load from 290 kg/day to 494 kg/day at the outlet. In 2011, Salajegheh *et., al* studied water quality in Karkheh watershed in West Iran and found that between the years 1988 and 2002, urban land in the watershed increased from 19,051 hectares to 27,794 hectares which increased total dissolved solids (TDS) in water from 1,200 mg/L to 1,900 mg/L at some points.[62] The study conducted by Khare *et., al* in the Alafia river watershed in Florida, USA, claimed that increasing urban area and decreasing agricultural land improved water quality.[63] They concluded that between the years 1974 and 2007, urban and residential land in the watershed increased from 10 to 21%, whereas, agricultural land decreased from 36 to 19% and forest reduction from 13 to 8%. This land use change decreased total nitrogen (TN) in stream water at some points from 2 mg/l to 1.5 mg/l.

Effects on Air Quality

LULC and their associations with the atmospheric surroundings is necessary for the sustainable management of natural property. In different South East Asian countries, LCLUC and their effects on atmospheric environment were studie.[64] Different landuse provide different benefits to residents i.e., liveable society. However, some land use generated or worsened the quality of air affecting the public health.[65,66] Most of the cities in South and South East Asia have many problems related to air quality, and endorsed to industrialization, urbanization and increasing demands from the energy sector.[67,68,69] Increased urbanization and population explosion have caused pressure for conversion of natural and agricultural areas into urban and residential areas and having considerable impacts on ecosystem.[70] Land use also impacts air quality by emitting GHG and disturbing aerosol composition.[71,72] It has been studied that pollutants and aerosols from burning of biomass exceeded standard levels[73,74,75,76] and transported to long distance and continue for weeks to months, affecting not only atmospheric environment but also disturbed smoke concentrations, biogeochemical cycles[77], including ozone concentrations[78], chemistry of atmospheric surroundings[79], weather andclimate.[80,81] Some of the workers mentioned that the unpredictable biogenic organic compounds (VOCs; e.g., isoprene, monoterpenes) and nitric oxide emitted from certain plants were major precursors for tropospheric ozone which is a influential GHG and an important air pollutant compound.[82] Biogenic VOCs are also chief precursors of secondary organic aerosols which add particulate matter to air quality.[83,84,85]

Changes in land cover also influenced the air pollutants deposition (such as ozone and PM) and their precursors. In the Houston, TX, landuse change effected on surface ozone area and it was found that the land use change increased the number of incredible ozone days (i.e., days with daily maximum 8-h ozone more than 84 ppb by 2–3 days) during summer.[86] The effects of anthropogenic land use change on atmospheric environment has been determined by Ganzeveld *et., al* and ignored the future potential of climate- driven changes in vegetation cover. They demonstrated how changes in landuse and landcover obsessed by climate change, anthropogenic land use changes and increasing atmospheric CO_2 concentrations, all disturb worldwide atmospheric environment and quality of air.[87] Investigations have been done by Manins *et., al* on the effects of six alternative forms of urban on atmospheric quality by using TOPAZ 2000 land use-transport model which is integrated with analytical air shed modelling for evaluating the impact on air quality of different urban development scenarios and found photochemical smog and particulate pollution.[88] In Wuhan city (Central China), impacts of land use on atmospheric quality has been examined and explored the quantitative connections between land use and air quality based on nine ground-level monitoring sites.[89] These monitoring sites have long-term spatio-temporal perception throughout the period from 2007 to 2014 and their results revealed that atmospheric environment has been significantly influenced by land use changes. Growth in one standard deviation of urbanized land caused 2% increases in NO_2 whereas plants caused decreases in 5%. The increasing numbers of water bodies with standard deviation of one were related with decrease in 3%–6% of SO_2 or PM_{10} level, which was equivalent to the mitigation consequence of meteorology factor like precipitation. The foremost sources of air pollution were industrial emission and vehicle exhaust, although urban land use patterns and changes also have a close relationship with urban atmospheric environment.[90,91] Another cause of deterioration of air quality from land use was the increasing urban temperature because of the increasing impermeable surface in the cities.[92,93] Generally, increasing temperature of urban areas resulted in higher concentration of ozone due to an increased ground-level ozone production.[94] In the Las Vegas Valley, US Xian (2007) also found clear local influence of urban development density on air pollutant distribution in 2007.[95] By using ground monitoring remarks and Land sat images for land use information, a moderate-to-strong connection was found between the annual average of $PM_{2.5}$ and the amount of urban land near by the monitoring sites in the years 1998 and 2010 within Central Alabama, US.[96]

Their main aim was to identify the interaction between PM_{10} variations and LUCC based on the simulated PM_{10} surfaces in the years 2006 and 2013 in the Changsha-Zhuzhou-Xiangtan agglomeration (CZT), by using a regression modeling. The grades

shown the overall mean of PM_{10} in the CZT declined from 106.74$\mu g/m^3$ to 94.37 $\mu g/m^3$ throughout the years 2006 and 2013. Generally, the variations in concentrations of PM_{10} were absolutely correlated with the increasing urbanized area, and negatively correlated with the increased forests areas. These consequence confirmed conclusion of in 2008 suggested that land use strategies such as urban growth and protecting essential ecological sites would be effective in limiting PM_{10} growth.[97, 98, 99] In 2017 Yang *et., al* identified the functional zone of urbanized area had an suitable spatial scale to examine the land use impact on $PM_{2.5}$ in urban areas since in a City of Nanchang city in middle China they well-known the land use impact on $PM_{2.5}$ pollution.[100] They explored the landuse impact on $PM_{2.5}$ pollution in urban areas by using land use regression (LUR) models and statistical analysis and did not find impact of change as the seasons changed. In 2015, at Raleigh situated in North Carolina Mansfield *et., al* found urban form effects on atmospheric surroundings air pollution and public health risk. For the development of three scenarios: compact development, sprawling development and current conditions, they incorporated health risk assessment models and land use regression transportation demand to forecast atmospheric quality and health impacts. According to their views, local variation in $PM_{2.5}$ increased by compactness and increases the harshness of confined air pollution hotspots and gave suggestions for improvement of air quality that there should be development in compactness from a regional point of view.[101]

Conclusions

Land-use impacts changed the water and air chemistry which can be significant and have a variety of temporal and spatial marks both positive and negative for humans and environment. It is demonstrated that from existing literature that researchers identified the potential consequences of various landuse changes and their management but the earlier studies did not found relationship between effect of these four landuses (agriculture, peri-urban, urban and forest) combined on water and air quality in hilly region. Therefore our main aim is to found a relationship between these four landuses and their effect on water (surface and groundwater) and air quality.

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