Estimating the relative magnitude of expected increases in soil erosion from tree clearing and agricultural development on Cape York

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Background Literature Review:

The relative magnitude of expected increases in soil erosion from tree clearing and agricultural development can be estimated from literature values calculated for Australia and Globally. As an international example, Nearing et al. (2017) documented that the average rates of soil erosion (sheet and rill) under natural, non-cropped conditions are less than 2 tonnes/ha/yr. Increases in soil erosion during and after clearing and agricultural development are well documented, with average rates of erosion on agricultural lands to on the order of 6 tonnes/ha/yr, or a greater than 3 fold increase. On more erodible soils with poor agricultural practices, agricultural erosion rates can average 15 t/ha/yr or more. Soil conservation practices help reduce soil erosion on agricultural lands, but with an average drop from 9 t/ha/yr to 6 t/ha/yr following soil conservation practise implementation (e.g., no-till, stubble retention, contour banks). Retiring lands from agriculture and returning it to a natural state can bring erosion rates down to 1 t/ha/yr or less (Nearing et al. 2017).

In Queensland grazing and cropping lands, net soil loss from sheet and rill erosion has been estimated to vary from 0 to 0.1 t/ha/yr for native grasslands and woodlands, to 2 to 4 t/ha/yr for modest to heavy grazing, to 1.3 to 14.7 t/ha/yr for cropping land (Loughran and Elliott 1996).

Sheet and rill erosion on grazed native woodland in central Cape York, Queensland, has been estimated to be on the order of 1 to 10 t/ha/yr under current land use (Lu et al. 2003). These rates have been estimated to have increased by 1.5 to 5 times since European settlement.

Specific sediment yields to the northern Queensland coasts (northeast coast and Gulf of Carpentaria) have been estimated to have increased from 0.69-0.86 t/ha/yr pre-European settlement to 2 t/ha/yr post-European settlement, due to land use and development (Wasson et al. 1996). In some areas such as the wet tropics and wet-dry savanna of northern Australia, increases in erosion from 2.6 to 4.5 above natural background rates have been documented. Greater than x10 increases in erosion have been documented in eastern Australia following land conversion from native pasture to cropping (Wasson et al. 1996).

These net (specific) yields to the coast depend on sediment delivery ratios from paddock to reef, with local erosion rates much higher than these catchment-wide averages, depending on land use, soil type, and geomorphology. In the Normanby basin, the sediment delivery ratios have been estimated to be ~ 45% for silt and clay sized sediment (Paddock to Reef model data, McCloskey et al. 2014). Howley et al. (2018 in press) documented an ~ 25% reduction in suspended sediment concentrations from the headwater to the coast, which is highly dependent on water volume dilution in the downstream direction and on particle size with higher clay suspension passing through the system into flood plumes than sand and coarse silt. Measured specific sediment yields in the Normanby River (not including the Kennedy River sub-basin) are ~ 0.1 t/ha/yr as a catchment wide average yield, indicating both loss of sediment and the lack of sediment production from expansive lower gradient floodplain lands, excluding the coastal zone (Brooks et al. 2013).

In the Normanby catchment, actual erosion rates have not been well quantified with field data at the paddock scale on agricultural lands, or on Tertiary plains and weathered alluvial soils proposed to be cleared for agricultural development.

Rainfall simulation measurements in the Normanby catchment (Rohde 2015) at the scale of 1.5 m x 1.5 m and an event rainfall of 80 mm/hr for one hour are comparatively useful for land use comparisons, but not equivalent to annual or annual average erosion rates or yield. They cannot be directly compared to other data reviewed here, due to issues scaling up event data from a plot to the hectare or farm scale. Regardless, measurements indicated that event mean concentrations (mg/L) were low for fruit orchards on deep red soil (89-250mg/L), modest for grazed pasture with good grass cover for brown (240 mg/L), red (317 mg/L), yellow (515 mg/L) and sodic (477 mg/L) soils, compared to high for banana cropping, inter-rows, and cereal cropping on deep red soils (2100-2300 mg/L), and very high for roads (3000-5000 mg/L) and gullies (11,300 mg/L) (Rohde 2015). These data suggest that agriculture land use on well drained red basalt soil could have erosion rates on the order of 0.6 to 1.1 tonnes/ha. The study highlighted the importance of grass cover to maintain low erosion rates on grazing pastures in brown, red, yellow and sodic soils. But the study did not quantify the magnitude of potential erosion from conversion of brown, yellow or sodic soils from grazing land use to cropping or horticulture, with likely erosion rates much greater than > 0.6 tonnes/ha in soils much more sensitive to erosion compared to basalt red soils.

On bedrock slopes with abundant coarse lithic fragments, Brooks et al. (2014) measured sheet erosion rates to vary from near 0 to 0.3 t/ha/yr. They documented that the semi-empirical RSULE equations overpredicted erosion on these slopes due to high rock cover content, incorrect soil erodibility factor, lack of erodible sediment supply on rocky slopes, and varying vegetation cover. This highlights the uncertainly of model predictions. However these low erosion values on rocky bedrock slopes are not applicable to other soil types proposed for agriculture in the Normanby catchment.

In the other extreme in the Normanby catchment, alluvial gully erosion into weathered floodplain soils has been measured to be on the order of 20-300 t/ha/yr, or greater in some circumstances (Shellberg and Brooks 2013; Brooks et al. 2013). This is similar to or slightly less than in the adjacent Mitchell catchment (Shellberg et al. 2013). Land use and over-grazing has initiated and accelerated gully erosion in the Normanby and Mitchell catchments (Shellberg and Brooks 2013; Shellberg et al. 2016).

Application to the Proposed Kingvale Station Agricultural Development:
On Kingvale Station in the Normanby catchment, it is proposed to clear 2,863 ha of woodland vegetation for agricultural development, specially sorghum (green chop) and other cropping production (Spies 2014).

If we assume from the data reviewed above that the current sheet erosion rate from this development site is conservatively on the order of 1 tonnes/ha/yr, and that agricultural production will increase this erosion rate by 3 times, then this agricultural development could increase erosion by 8,589 tonnes/yr. A 6 fold increase in erosion to 6 t/ha/yr (a decent global average for agricultural cropping land), would increase erosion by 17,178 t/yr.

This estimated increase in sheet and rill erosion does not taken into account increased erosion from either 1) gully erosion accelerated by land use, or 2) road and fence-line erosion associated with linear disturbance. There are approximately 10km of gully prone drainage features within or immediately downstream of the proposed development (dambos in Shellberg 2016). If the ultimate gully erosion width is 20m, this would equate to 20 ha of potential future gully erosion. At a catchment average gully erosion rate of 100 t/ha/yr, gully erosion at the development site could produce ~ 2000 t/yr of sediment at peak development. Assuming 20 km of road and fence-line development with 10 m wide disturbance, then 20 hectares of disturbance at ~ 20 t/ha/yr would produce an additional 400 t/yr of sediment. Bed and bank erosion increases along creeks are not included or estimated.

It is therefore estimated that this agricultural development could increase total erosion by 10,989 t/yr to 19,578 t/yr of combined sheet, rill, road, and gully erosion.

For net sediment budget calculations, it is assumed that the sediment delivery ratio of hillslopes is 10% to the stream network, the sediment delivery ratio of fine sediment from streams, gullies, roads and fences (linear erosion features) is 45% to the estuary, and 60% of the eroded soil is fine sediment (silt and clay particle sizes). From these estimates, the Kingvale development could increase sediment loads to Princess Charlotte Bay by 232 to 464 t/yr from agricultural slopes, 108 t/yr from road and fence erosion, and 540 t/yr from gully erosion, for a total of 880 to 1112 t/yr.

As a comparison, the suspended sediment river load estimated by model to exit the Normanby/Kennedy River sytem to the GBR is 1,392,000 tonnes/yr (from total inputs before partial storage of 3,000,000 tonnes per year) (Brooks et al. 2013). Therefore, 2,863 ha of cropping and associate road, fence and gully disturbance at Kingvale could increase river sediment yields by 0.06% to 0.08%.

This increase in sediment load would also be accompanied by increased nitrogen and phosphorous pollution associated with nutrients attached to soils, and imported nutrients applied to grow crops, discharged through erosion or leakage through sandy soils.

Currently, the Commonwealth Government through the Department of Environment and the Reef Trust are investing millions of dollars in Great Barrier Reef catchments to reduce sediment and nutrient pollution delivered to the Great Barrier Reef Lagoon. The average real-world cost paid by the government to reduce or abate sediment pollution on grazing, cropping, or gully lands is on the order $450 per tonne/yr of fine sediment delivered to the GBR Lagoon (Giles West and Scott Wilkinson, personal communication 2017), which was higher in the recent past ($600/t/yr, Kevin Gale, Reef Rescue presentation 2013). From these data, the cost of increasing fine sediment pollution (880 t/yr to 1112 t/yr) from agricultural development on Kingvale Station delivered to the Great Barrier Reef (GBR) Lagoon is approximately $400,000 to $500,000 in real world pollution costs. Nutrient or pesticide pollution costs are not included in these estimates.

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